National Park Service
U.S. Department of the Interior

Natural Resource Program Center
Fort Collins, Colorado

National Capital Region Network 2005 - 2006 Water Resources Monitoring Report

Natural Resource Technical Report NPS/NCRN/NRTR—2007/066

ON THE COVER
Marian Norris collecting water samples from Big Hunting Creek in Catoctin Mountain Park, Thurmont, MD
Photograph by: I&M field technicians

National Capital Region Network 2005 - 2006 Water Resources Monitoring Report

Natural Resource Technical Report NPS/NCRN/NRTR—2007/066

Marian Norris
John Paul Schmit
James Pieper
National Park Service
Inventory and Monitoring Program
National Capital Region Network
4598 MacArthur Blvd., NW
Washington, DC 20007

December 2007

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The Natural Resource Publication series addresses natural resource topics that are of interest and applicability to a broad readership in the National Park Service and to others in the management of natural resources, including the scientific community, the public, and the NPS conservation and environmental constituencies. Manuscripts are peer-reviewed to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and is designed and published in a professional manner.

The Natural Resources Technical Reports series is used to disseminate the peer-reviewed results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service's mission. The reports provide contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations. Current examples of such reports include the results of research that addresses natural resource management issues; natural resource inventory and monitoring activities; resource assessment reports; scientific literature reviews; and peer reviewed proceedings of technical workshops, conferences, or symposia.

Printed copies of reports in these series may be produced in a limited quantity and they are only available as long as the supply lasts. This report is also available from the National Capital Region Network I&M Network website (http://science.nature.nps.gov/im/units/ncrn/monitoring_water.cfm) on the internet, or by sending a request to the address on the back cover.

Please cite this publication as:

Norris, M. E., J. P. Schmit, J. M. Pieper. 2007. National Capital Region Network 2005 - 2006 Water Resources Monitoring Report. Natural Resource Technical Report NPS/NCRN/NRTR 2007/066. National Park Service, Fort Collins, Colorado.

NPS D-77, December 2007

TABLE OF CONTENTS

List of Tables

List of Figures

Executive Summary

In 2005, the National Capital Region Inventory and Monitoring Network (NCRN) initiated a long-term water quality and quantity monitoring program, funded in part by the Water Resources Division. The program is carried out through monthly sampling at more than 50 sites within 10 of the NCRN parks. This report summarizes and analyzes the preliminary Water Chemistry and Nutrient Dynamics findings through 2006.

Parks monitored for this report include Antietam National Battlefield, Catoctin Mountain Park, Chesapeake and Ohio Canal National Historical Park, Harpers Ferry National Historical Park, George Washington Memorial Parkway, Manassas National Battlefield Park, Monocacy National Battlefield, National Capital Parks - East, Prince William Forest Park, Rock Creek Park, and Wolf Trap National Park for the Performing Arts. The streams monitored are all part of the Potomac River Watershed. The Potomac is the second largest drainage of the nine river basins that form the 64,000 square mile Chesapeake Bay watershed.

Water chemistry is important to maintaining a healthy habitat for many aquatic organisms, wildlife, and humans. Water Quality can provide insights into overall system productivity, shift species abundances and distributions, and alter nutrients cycles. Water quality parameters such as pH, specific conductance, dissolved oxygen, and temperature are good measurements that provide an overview of water quality. Water quality monitoring is required to comply with relevant environmental legislation and NPS mandates and to evaluate potential stressors in NCRN waters.

One of the major findings, though not unexpected, of this program is that phosphorus levels at all sites exceed the ecological eutrophication threshold nearly 100% of the time. A majority of the sites also showed elevated levels of nitrate that exceeded the established ecological threshold. Nitrate and phosphorus are nutrients of primary concern in efforts to improve the ecological condition of the Potomac River and the Chesapeake Bay. Sources for these nutrients are not fully identified. Ammonia levels rarely exceeded the established thresholds. Repeated exceedances occurred at single sites, suggesting that there is a localized upstream source.

A number of the sites sampled exhibited levels of dissolved oxygen that were below the threshold that supports stream life, occasionally for months at a time. Several of the same sites also possessed measures of specific conductance that exceeded levels known to stress the biological stream community.

Acid neutralizing capacity at all sites never exceeded the established threshold. This indicates that currently none of the parks or their streams are in danger of succumbing to acidification. Very few exceedances of pH measurements were found throughout the sampling in 2005 and 2006, often at a very localized scale, temporally and spatially.

The table on the following page summarizes the data collected, at the park level. All collected measurements at each site were utilized to provide a mean and range for the parameters detailed in this report.

Table 1: Mean, Range, and Threshold for water chemistry and nutrient, at the park-level.

Park	DO (%)			DO (mg/L)			pH			Specific Conductance		
	Mean	Range	Threshold	Mean	Range	Threshold	Mean	Range	Threshold	Mean	Range	Threshold
ANTI	81.1	19.0 - 107.0	--	8.46	1.98 - 11.55	> 5.00	8.16	7.67 - 8.36	6.0<x<8.5	532.4	0.0 - 657	< 400.0
CATO	69.7	22.3 - 98.2	--	7.76	2.69 - 12.37	> 5.00	7.46	6.71 - 8.12	6.0<x<8.5	147.7	73.8 - 1313	< 400.0
GWMP	68.8	17.3 - 100.5	--	7.21	1.88 - 11.50	> 5.00	7.66	6.72 - 9.19	6.0<x<8.5	397.0	127.6 - 3629	< 400.0
HAFE	70.7	21.4 - 105.8	--	7.57	2.10 - 13.10	> 5.00	8.21	7.67 - 8.59	6.0<x<8.5	640.2	374.1 - 1029	< 400.0
MANA	64.2	11.3 - 116.0	--	7.23	0.98 - 15.25	> 5.00	7.49	6.56 - 8.28	6.0<x<8.5	397.4	163.8 - 994	< 400.0
MONO	70.6	2.3 - 114.8	--	7.53	0.16 - 13.13	> 5.00	7.88	6.82 - 9.42	6.0<x<8.5	342.2	188.0 - 634	< 400.0
NACE	73.2	23.3 - 152.0	--	7.17	2.27 - 12.68	> 5.00	7.35	6.35 - 9.38	6.0<x<8.5	324.1	177.7 - 495.8	< 400.0
PRWI	69.6	32.4 - 104.9	--	7.40	1.38 - 11.76	> 5.00	6.93	5.88 - 13.00	6.0<x<8.5	60.0	20.6 - 366.9	< 400.0
ROCR	65.8	10.4 - 160.4	--	7.12	0.89 - 13.84	> 5.00	7.78	6.83 - 8.95	6.0<x<8.5	730.3	209.5 - 4168	< 400.0
WOTR	69.4	18.3 - 95.4	--	7.84	1.89 - 18.94	> 5.00	7.20	6.41 - 7.70	6.0<x<8.5	331.7	153.7 - 1089	< 400.0

Park	Acid Neutralizing Capacity			Nitrogen - Ammonia (mg/L)			Nitrogen - Nitrate (mg/L)			Phosphate (mg/L)		
	Mean	Range	Threshold	Mean	Range	Threshold	Mean	Range	Threshold	Mean	Range	Threshold
ANTI	3937	2100 - 4820	> 600	0.088	0.000 - 0.559	< 0.442	8.6	2.1 - 14.3	< 2.0	1.04	0.16 - 2.03	< 0.1
CATO	539	280 - 960	> 200	0.031	0.000 - 0.117	< 0.442	0.7	0.1 - 1.3	< 2.0	0.78	0.07 - 4.42	< 0.1
GWMP	1059	178 - 4950	> 200	0.029	0.000 - 0.147	< 0.442	1.6	0.5 - 2.8	< 2.0	1.46	0.04 - 5.75	< 0.1
HAFE	4390	2800 - 5280	> 600	0.213	0.000 - 1.314	< 0.442	5.6	0.3 - 9.3	< 2.0	0.72	0.18 - 1.31	< 0.1
MANA	1518	600 - 3752	> 200	0.066	0.000 - 0.700	< 0.442	0.4	0.1 - 0.6	< 2.0	0.74	0.10 - 5.83	< 0.1
MONO	1376	616 - 3500	> 600	0.055	0.000 - 0.180	< 0.442	3.6	0.2 - 14.2	< 2.0	0.84	0.04 - 4.66	< 0.1
NACE	864	290 - 1702	> 200	0.103	0.000 - 0.500	< 0.442	0.6	0.2 - 1.3	< 2.0	1.26	0.05 - 8.80	< 0.1
PRWI	306	136 - 776	> 200	0.037	0.000 - 0.600	< 0.442	0.4	0.1 - 1.9	< 2.0	1.09	0.04 - 5.89	< 0.1
ROCR	1579	544 - 5800	> 200	0.115	0.000 - 0.887	< 0.442	2.7	0.3 - 13.5	< 2.0	1.21	0.06 - 8.82	< 0.1
WOTR	615	334 - 920	> 200	0.134	0.000 - 1.440	< 0.442	1.5	0.8 - 2.2	< 2.0	2.31	0.12 - 10.20	< 0.1

Introduction

Almost all of the parks in the National Capital Region Inventory and Monitoring Network (NCRN) lie within the Potomac River watershed with the exception of parts of Suitland Parkway and Baltimore and Washington Parkway of NACE, which are located in the Patuxent River watershed.

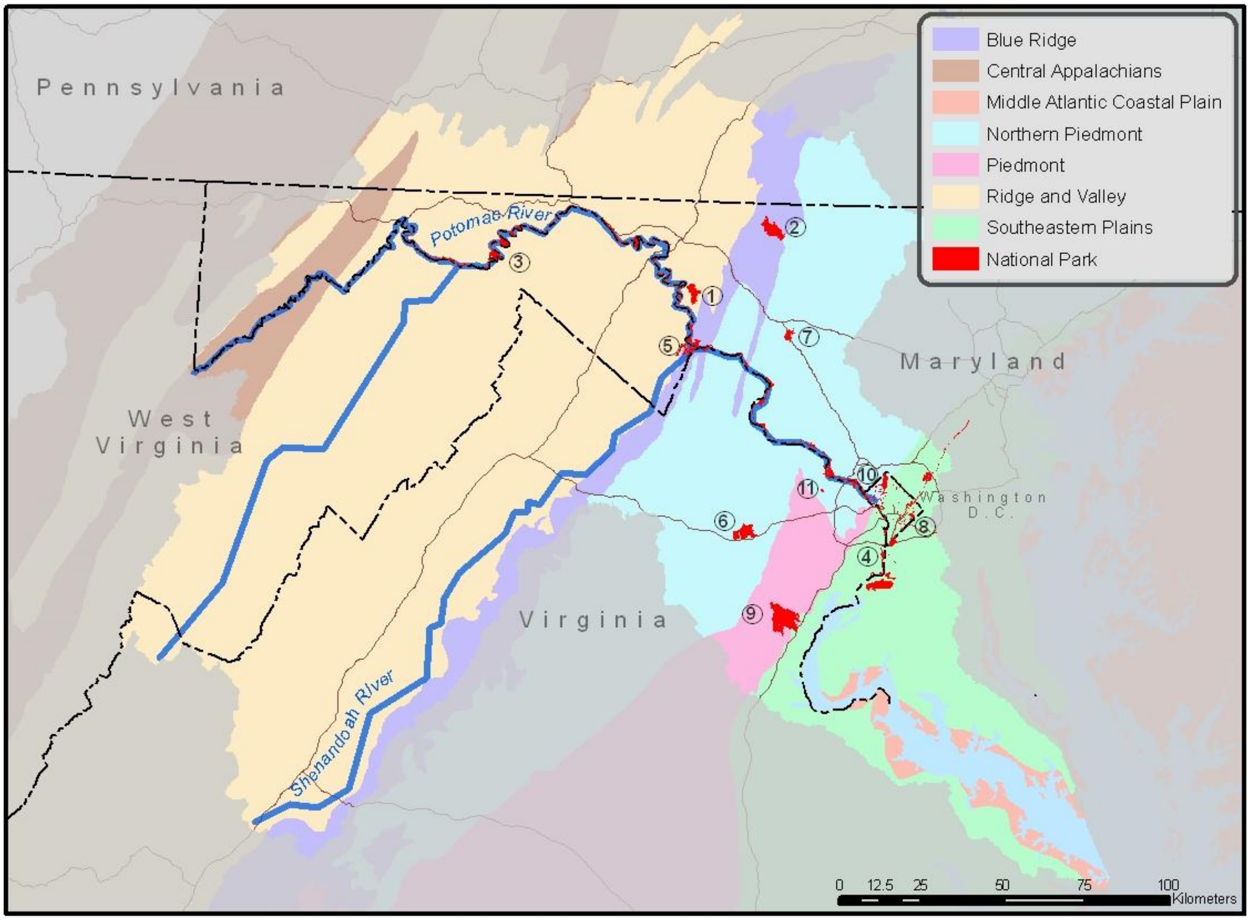

Figure 1 : Locations of the National Parks (red) in the National Capital Region within the Potomac River Watershed

1. Antietam National Battlefield
2. Catoctin Mountain Park
3. Chesapeake & Ohio Canal National Historical Park
4. George Washington Memorial Parkway
5. Harpers Ferry National Historical Park
6. Manassas National Battlefield Park
7. Monocacy National Battlefield
8. National Capital Parks–East
9. Prince William Forest Park
10. Rock Creek Park
11. Wolf Trap National Park for the Performing Arts

The Potomac River Watershed covers seven physiographic regions and subregions. Sixty percent of the stream's reaches are first order, the rest are second or higher. Though several parks (George Washington Memorial Parkway, Chesapeake and Ohio Canal National Historical Park, National Capital Parks – East, Harpers Ferry), are adjacent to the river, the parks do not manage the waters of the Potomac. The waters of the Potomac River are owned by the state of Maryland. The river bottom running through the District of Columbia is owned by the National Park Service (NPS).

The Potomac is the second largest drainage of the nine river basins that form the 64,000 square mile Chesapeake Bay watershed. The Chesapeake Bay is the largest estuary in the United States, providing habitat for abundant and diverse wildlife populations and supporting an economy that includes fishing, shipping, and recreation. Currently, 136 million people live in the Chesapeake Bay watershed, which is challenged with unprecedented development (Burke *et al*., 1999).

Parks with natural water resources in the Region include Antietam National Battlefield, Catoctin Mountain Park, Chesapeake and Ohio Canal National Historical Park, Harpers Ferry National Historical Park, George Washington Memorial Parkway, Manassas National Battlefield Park, Monocacy National Battlefield, National Capital Parks - East, Prince William Forest Park, Rock Creek Park, and Wolf Trap National Park for the Performing Arts.

The National Capital Region Inventory and Monitoring Network's (NCRN) long-term water monitoring program, funded in part by the Water Resources Division, is designed to ensure the National Capital Region's parks possess science-based information needed for effective resource management. To achieve this, program staff collects data for the following vital signs: water chemistry, nutrient dynamics, surface water dynamics, physical habitat index, aquatic macroinvertebrates, and fishes.

A Water Chemistry Monitoring Protocol was developed in house which includes nutrient dynamics. In collaboration with the USGS, we developed a Surface Water Dynamics protocol, and in collaboration with researchers from Frostburg State University and The Maryland Department of Natural Resources, we worked to adapt the Maryland Biological Stream Survey for use in NCRN parks, which includes the physical habitat index, aquatic macroinvertebrates, and fish vital signs. This year's report will only contain the Water chemistry monitoring data. The Surface Water Dynamics data will be summarized beginning next fiscal year. Data analysis on the Biological Stream Survey (BSS) data will be published every five years when a full survey of the parks is completed.

Surface Water Quality is important to maintaining a healthy habitat for many aquatic organisms, wildlife, and humans. Water Quality can provide insights into overall system productivity, shift species abundances and distributions, and alter nutrients cycles. Water quality parameters such as pH, specific conductance, dissolved oxygen, and temperature are good measurements that provide an overview of water quality. Water quality monitoring is required to comply with relevant environmental legislation and NPS mandates and to evaluate potential stressors in NCRN waters.

Monitoring Questions to be addressed by the Water Chemistry Monitoring Protocol:

- What are the long-term trends in water quality in the parks?
- What are key pollution sources to streams in NCRN parks?
- Is the ANC sufficient in streams within the NCRN to withstand regional acidity inputs?

Measurable Objectives of the Water Chemistry Monitoring Protocol:

1. Assess variance in temperature, specific conductance, pH, dissolved oxygen, nutrients and ANC in priority streams of the NCRN, on a diurnal and seasonal basis as well as over the long term
2. Assess trends in temperature, specific conductance, pH, dissolved oxygen, nutrients and ANC within and between watersheds and stream orders with reference to (a) urban reference streams drawn from MBSS and/ or NAWQA data in the region and/or (b) comparison of current to past condition.
3. Assess stream condition by identifying single parameters with values out of bounds (a) biologically (determined through literature search), (b) according to drinking water standards, (c) according to EPA and State designated use standards, or (d) of previous variability
4. Provide information for Resource Stewardship Strategies and Annual GPRA reporting

Methods

Sampling Site Locations

As determined by the Science Advisory Committee, surface water types in the NCRN parks that are deemed significant or important candidates for long term monitoring include flowing water such as streams, rivers, and groundwater; and still water such as wetlands and vernal pools. The Water Quality Monitoring Program funded by WRD is primarily interested in the set of all 1st to 4th order non-tidal freshwater streams in the parks of the National Capital Region Network depicted on current USGS 1:24,000 topographic maps. Due to the broad nature of I&M's monitoring efforts, the remaining surface water types will be monitored as funding and manpower is available.

The sample design for streams is based on a map of streams (defined at a scale of 1:24,000) bisected by park boundaries. Since the water chemistry monitoring sites serve as the pool from which the biological sampling sites are chosen, stream segments in the parks less than 75m in length were eliminated (the length used for BSS sampling). Strahler stream order (Strahler 1952) was calculated for each stream segment in the park. Sampling of streams will focus on those segments of streams that are the furthest downstream and still in park boundaries. Measurements downstream generally reflect conditions in the watershed upstream**.** Where possible, multiple steams within each watershed will be sampled to provide information at the watershed level.

During the 2005-2006 sampling season a total of 39 sites were sampled. These sites will continue to be monitored every month for the extent of this program. Additional sites that were initially rejected due to uncertainty about their flow status (perennial or ephemeral) will be added in the 2007-2008 sampling season. Stream sections will be verified for their appropriateness as sampling locations. Park Personnel and outside researchers have noted that the NHD is missing a few streams known to be perennial and contain sufficient flow to support fish (ex: Ike Creek, CATO) and that many of the streams depicted as 1st order are ephemeral or never contain flow. Therefore the initial sampling pool will exclude streams depicted as 1st order until they are ground-truthed. All streams at NACE will be verified for appropriateness, due to their urban nature and uncertainty about where head of tide occurs on park property. Sampling requires 75m of non-tidal stream. Once all the 1st order streams are verified, they will be added to the sampling pool (at the latest by the 5 year review in 2010) and the sampling schedule will be re-evaluated to accommodate all of the streams.

Table 2: Number of streams > 75m in length within the park Boundary by Strahler stream order (as depicted on NHD)

Park name	Park abbreviation	1st	2nd	3rd	4th	5th	6th	streams monitored	Locations rejected
Antietam National Battlefield	ANTI	4			1			1	4
Catoctin Mountain Park	CATO	7	2					3	6
Chesapeake and Ohio Canal National Historical Park	CHOH	160	38	18	10	5	3	0	234
George Washington Memorial Parkway	GWMP	6	4	4	1			5	10
Harpers Ferry National Historical Park	HAFE	3	1					1	3
Manassas National Battlefield Park	MANA	16	4	1				4	17
Monocacy National Battlefield	MONO	3	3	2	1			3	6
National Capital Parks-East	NACE	8	3					5	6
Prince William Forest Park	PRWI	50	5	2	1			6	52
Rock Creek Park	ROCR	11	2		2			9	6
Wolf Trap National Park for the Performing Arts	WOTR	2	1					2	1
	Totals:	270	63	27	16	5	3	39	348

No sites are monitored in CHOH at this time. The linear nature of the park and the large number of streams that cross it provide additional challenges to water monitoring. Each individual stream is within the park for only a short distance, and drains only a small portion of the park. Due to these factors the park has little control over the water quality of most of these streams, and each individual stream has a small impact on the park as a whole. Therefore it is difficult to design an appropriate sampling effort that proved both affordable and meaningful. However, the unique orientation of the park and its length may actually be a benefit with respect to water sampling. The state of Maryland's Department of Natural Resources has a comprehensive biological sampling program that is spatially and temporally designed to provide statistically valid estimates of stream health across the state and within specific watersheds based on a stratified random sampling design. In future versions of this report we will attempt to summarize this data collected by the state and local governments.

One of the biggest advantages of using a modified version of the Maryland Biological Stream Survey to sample waters in the region is that all of the data is collected in the same way; the only thing that differs is the spatial design of the sampling in the parks. For example, 169 locations in Allegheny County watersheds draining into the Potomac River have been sampled during the two rounds of MBSS sampling so far, and additional sites are planned for the next round. Any data collected in ANTI, HAFE, MONO, CATO, ROCR, or a couple of Clara Barton parkway sites would also apply to a water quality summary for CHOH, since their streams flow into watersheds that cross the park. For more information see the Biological Stream Survey Protocol for the NCRN.

Table 3: Water Chemistry Monitoring Sites excluding CHOH streams

Stream	Physiographic Region	State	County
Antietam National Battlefield			
Sharpsburg Creek	Ridge & Valley	MD	Washington
Catoctin Mountain Park			
Big Hunting Creek	Blue Ridge	MD	Frederick
Whiskey Still Creek	Blue Ridge	MD	Frederick
Owens Creek	Blue Ridge	MD	Frederick
George Washington Memorial Parkway			
Mine Run	Piedmont	VA	Fairfax
Turkey Run	Piedmont	VA	Fairfax
Minnehaha Creek	Piedmont	MD	Montgomery
Difficult Run	Piedmont	VA	Fairfax
Pimmit Run	Piedmont	VA	Arlington
Harpers Ferry National Historical Park			
Flowing Springs Run	Ridge & Valley	WV	Jefferson
Manassas National Battlefield			
Dogan Branch	Piedmont	VA	Prince William
Chinn Branch	Piedmont	VA	Prince William
Holkums Branch	Piedmont	VA	Prince William
Youngs Branch	Piedmont	VA	Prince William
Monocacy National Battlefield			
Visitor's Center Creek	Piedmont	MD	Frederick
Hardings Run	Piedmont	MD	Frederick
Bush Creek	Piedmont	MD	Frederick
National Capital Parks - East			
Still Creek	Coastal Plain	MD	Prince Georges
Ft. Dupont	Coastal Plain	MD	Prince Georges
Henson Creek	Coastal Plain	MD	Prince Georges
Oxon Run	Coastal Plain	MD	Prince Georges
Unnamed Tributary Accokeek Creek	Coastal Plain	MD	Prince Georges
Prince William Forest Park			
North Fork Quantico Creek	Coastal Plain	VA	Prince William
South Fork Quantico Creek	Coastal Plain	VA	Prince William
Sow Run	Piedmont	VA	Prince William
Mary Bird Branch	Coastal Plain	VA	Prince William
Middle Branch Chopawamsic Creek	Piedmont	VA	Stafford
North Branch Chopawamsic Creek	Piedmont	VA	Prince William
Rock Creek Park			
Rock Creek before confluence w/ Fenwick Branch	Piedmont	DC	Washington
Fenwick Branch	Piedmont	DC	Washington
Pinehurst Branch	Piedmont	DC	Washington
Luzon Branch	Piedmont	DC	Washington
Broad Branch	Piedmont	DC	Washington
Soapstone Valley Creek	Piedmont	DC	Washington

Hazen Creek	Piedmont	DC	Washington
Piney Branch	Piedmont	DC	Washington
Rock Creek below National Zoo	Coastal Plain	DC	Washington
Palisades Creek	Piedmont	DC	Washington
Wolf Trap National Park for the Performing Arts			
Wolf Trap Creek	Piedmont	VA	Fairfax
Courthouse Creek	Piedmont	VA	Fairfax

Site Selection Criteria, Stratification, and Randomization

Water bodies or streams may be excluded due to one or more of the following:

Ephemeral drainages—any water body that is not a wadeable or perennial stream is automatically not included as a target waterbody. Ephemeral drainages are not typically included since they are only flowing during storm events. These types of drainages are also often hidden in deep brush, located on steep slopes, or otherwise difficult to access.

Streams located primarily off parklands—Water bodies with only small portions on park property are often located in urban areas where volunteer recruitment would be probable or where monitoring activities currently exist. This also includes waterbodies that are located within the park legislative boundary but not managed by the park (and particularly areas where NPS staff access is restricted). This exclusion applies to much of CHOH.

Adequate monitoring by other entities—Water bodies consistently monitored by other entities need not be monitored. It is appropriate and fiscally responsible not to monitor these streams if the parks have access to the data and the data meets the needs of the monitoring program. This exclusion applies to much of CHOH.

It was initially envisioned that once the list of potential monitoring locations was developed; a randomization process would be used to determine which would actually be sampled. However the final list was short enough that it was decided to sample all of them rather than a random subset.

Sampling Frequency and Replication

Currently, all parameters are measured on a monthly basis. The in situ measurements (temperature, pH, DO, specific conductance, salinity) are determined utilizing handheld instruments. ANC and nutrient samples (nitrate, total phosphorus, ammonia) are collected monthly to establish a baseline and to examine for seasonal and annual trends. At this time, monitoring will continue on a monthly basis through 2007.

In order to determine the occurrence of temporal trends in the streams, Hydrolab Datasondes may be intermittently deployed at various sites to collect continuous data over several weeks/months. The collected data would be compared to regional precipitation records to determine if spikes occur during flood, base flow, or first flush with rain event. This would provide insight into what additional water quality information is made apparent by sampling at shorter measurement intervals (e.g. capture diurnal or seasonal fluctuations) or may be missed entirely by grab sampling between extreme weather events (e.g. first flush effects on chemical load). Establishing the normal range or variance of these parameters at a site over the long term may be important for time-series monitoring purposes (Freshwater Workgroup Subcommittee, 2002).

Generally, for discontinuous sampling to approach the level of completeness of continuous sampling, water bodies must be sampled manually at very regular (short) intervals, (e.g. at the same time of day, and at multiple periods of the day when diurnal and other effects on various parameters are at their extremes). Other longer cycle maxima/minima (e.g. freeze/thaw, peak/low flow etc.) are also encountered in discontinuous sampling only rarely (usually fortuitously), despite their importance in understanding a water body's physical-chemical ebb and flow and in understanding the effects parameter changes have on aquatic organisms. Discontinuous monitoring can provide a wider range of parameters using sampling suites under a variety of flow conditions. Intermittent monitoring also does not generate the large volume of data that must be reviewed and corrected that continuous monitoring data does, so can be less costly to handle and less labor intensive to manage.

Data Collection

We collect data for temperature, dissolved oxygen, specific conductance, pH, acid neutralizing capacity, nutrients (ammonia, nitrate, and total phosphorus), and flow (for detailed instructions see Norris et al., 2007). These parameters provide information that characterize a waterbody or stream segment, are fundamental components of monitoring and regulatory programs, and are relatively easy to measure with multi-parameter probes or Hach test kits. The Water Resources Specialist and Hydrologic Technician collect in situ data with handheld meters, a YSI-63 pH meter and a YSI-85 Dissolved Oxygen meter, once a month at every perennial wadeable stream in the parks for temperature, dissolved oxygen, specific conductance, salinity and pH. At the same time samples are collected and brought back to the lab for acid neutralizing capacity analysis by titration with HACH reagents. Ammonia, nitrate, and total phosphorus analysis using Hach reagents and equipment, a Hach DR4000/U spectrophotometer. These parameters provide information that characterize a waterbody or stream segment, are fundamental components of monitoring and regulatory programs, and are relatively easy to measure with multi-parameter probes or Hach test kits. Sites are photographed during each sampling visit to provide a visual record of existing conditions.

Parameters

The specific parameters for which data is presented in this report are described in detail below. Park specific information for each parameter is included in each park's summary.

Acid Neutralizing Capacity (ANC)

ANC is the prime indicator of a waterbody's susceptibility to acid inputs. ANC is a measure of the amount of carbonate and other compounds in the water that neutralize low pH. The pH of water does not indicate its "buffering capacity", which is controlled by the amounts of alkalinity and acidity present. ANC is typically caused by anions in natural waters that can enter into a chemical reaction with a strong acid. These are primarily the carbonate (CO_3^{-2}) and bicarbonate (HCO_3^-) ions. Dissolution of these species is most typically caused by the partial pressure of CO^2 in the atmosphere but their presence may be further elevated in areas of carbonate rock dissolution where waters are often of a bicarbonate type (elevated in HCO_3^-). Borates, phosphates, silicates, arsenate, ammonium and organic ligands (e.g. acetate and propionate) can also contribute to alkalinity when present. However, except for unusual natural waters or waters significantly impacted by anthropogenic sources, non-carbonate ionized contributors are rarely present in large enough quantities to affect alkalinity or ANC determinations (Wilde and Radke 1998).

ANC is particularly important to measure in areas where acid mine drainage (e.g. PRWI) or acid precipitation (entire NCRN) is a potential concern. Acid sensitive waters generally have specific conductance below 25 µS/cm, acid neutralizing capacity (ANC) below 100 µeq/L for episodic acidification (50 µeq/L l for chronic acidification), total base cation (calcium, magnesium, sodium, and potassium) concentration below 100 µeq/L, and pH below 6.0. Some references state that surface waters with ANC less than or equal to 200 µeq/L are considered sensitive to acidification (Turk and Spahr 1989). In karst terrain, ANC below 600 µeq/L $CaCO_3$ is cause for concern. NPS-WRD (2002) indicates that surface waters in three parks—Antietam National Battlefield, Chesapeake and Ohio Canal National Historical Park and Manassas National Battlefield were not susceptible to acidification from atmospheric deposition. However this data ranges in age from 8 to 30 years and circumstances may have changed.

NCRN utilizes Hach Alkalinity Method 8203 (Sulfuric Acid Method) to determine phenolphthalein and total alkalinity which are used to calculate the acid neutralizing capacity.

Dissolved Oxygen

Dissolved oxygen (DO) concentration of surface water is dependent on water temperature and air pressure, and, to a lesser extent, the amount of dissolved ions (measured as salinity or conductivity - correction factors for salinity are normally applied after measuring DO). It is a measure of the amount of oxygen in solution. DO enters the water from one of two ways– photosynthesis of plants and directly from the atmosphere via diffusion or mechanical aeration (e.g., waves, waterfalls). Principal sources of dissolved oxygen in surface waters include dissolution of atmospheric oxygen in water as oxygen is depleted (re-aeration) and photosynthetic activities of aquatic plants. The primary sinks of DO include respiration and biochemical oxygen demand (BOD). Because oxygen is sparingly soluble, the balance between sources and sinks can be easily upset leading to oxygen extremes of supersaturation or total/near total depletion (NPS-WRD 2002; Stednick and Gilbert 1998; USGS 1980).

The higher the pressure and cooler the temperature, the more oxygen from the atmosphere can be dissolved into the water until equilibrium is reached; this is called saturation (Hem 1989; Radtke et al. 1998). Oxygen has strong daily and seasonal variability. In organically enriched streams, DO is often lowest just before sunrise because plants have not been photosynthesizing and only respiration has been occurring. Conversely, DO increases after sunrise until the sun's angle of incidence is greatest because the rate of photosynthesis is dependent on sunlight. In less enriched streams, this pattern may be less apparent or absent because stream temperatures are lower at night and thus can contain more dissolved oxygen. Due to these daily patterns, it is important to always monitor a particular site at the same time of day.

It is essential that consideration of the natural regimes of DO be included in applying criteria to specific water bodies. Higher absolute concentrations of dissolved oxygen (mg/L) at saturation are achievable in the natural environment under conditions of higher atmospheric pressure and lower temperature and lower dissolved solids content of the water. Thus, water bodies occurring at higher elevations, subject to a barometric low pressure system, or having warmer temperatures and/or higher dissolved solids content would be expected to contain less dissolved oxygen at saturation. Supersaturation of surface water with respect to dissolved oxygen may also result from turbulence associated with high gradient streams or waterfalls. In rocky, high gradient streams, mechanical aeration is often great enough that even streams with highly elevated oxygen demand are at or near saturation levels. In low gradient coastal plain systems, even moderate oxygen demand (referred to as BOD or biochemical oxygen demand) can result in DO levels that are low enough to harm aquatic biota (NPS-WRD 2002; Stednick and Gilbert 1998; USGS 1980).

DO is necessary in aquatic systems for the survival and growth of many aquatic organisms. The presence and amount of dissolved oxygen in surface water also determines the extent to which many chemical and biological reactions will occur (Wilde and Radke 1998). Low dissolved oxygen is of greatest concern due to detrimental effects on aquatic life. Conditions that generally contribute to low DO levels include warm temperatures, low flows, water stagnation and shallow gradients (streams), organic matter inputs, and high respiration rates. Decay of excessive organic debris that are in the water column from aquatic plants, municipal or industrial discharges, or storm runoff can also cause dissolved oxygen concentrations to be undersaturated or depleted. Insufficient DO can lead to unsuitable condition for aquatic life, and its absence can result in the unpleasant odors associated with anaerobic decomposition. Furthermore, the presence of toxic substances such as cyanides and some metals can exacerbate the lethal effects of low concentrations of DO. Minimum required DO concentration to support fish varies because the oxygen requirements of fish vary with a number of factors, including the species and age of the fish, prior acclimatization, temperature, and concentration of other substances in the water.

NCRN utilizes a Yellow Springs Institute (YSI) handheld meter model number 85 to measure the percent saturation and concentration of dissolved oxygen .

Nitrogen-Ammonia

Nitrogen in surface water may occur in dissolved or particulate form and result from inorganic or organic sources. The dissolved, inorganic forms of nitrogen are most available for biological uptake and chemical transformation that can lead to eutrophication of water bodies. Inorganic forms of nitrogen are ammonia (NH_3), its more common oxidized form, ammonium ion (NH_4^+), nitrate (NO_3^-), and nitrite (NO_2-). Nitrite is rare in unpolluted waters. The organic form of nitrogen is typically un-ionized ammonia (NH_3) that primarily results from the bacterial decay of humic matter or urea from animal or human waste (agricultural waste lagoons or POTWs). These organically sourced forms of nitrogen occur in various molecular chains of H-N or C-H-N with limited biological uptake (10-20%) potential. However, ammonia (NH_3) is a more toxic form of nitrogen with an aquatic life toxicity that varies with pH and temperature.

Ammonia is typically indicative of agricultural pollution or anaerobic degradation of nitrogen containing compounds. Higher temperatures also favor the uptake of ammonia (movement across membranes, e.g. gills) by aquatic organisms causing the Chronic Criteria (CCC) for aquatic organisms to lower as temperature increases. The lowest value for CCC is 0.442 mg/L NH_3. Ammonia (NH_3) is a more toxic form of nitrogen with an aquatic life toxicity that varies with pH and temperature. Ammonia is a major limiting nutrient in most aquatic systems an increase of which may result in eutrophication. It is typically indicative of agricultural pollution or anaerobic degradation of nitrogen containing compounds such as humic matter or urea from animal or human waste (agricultural waste lagoons or POTWs). Ammonia is also bioavailable to plants including phytoplankton. When ammonium ion is in high concentrations in natural waters containing oxygen, it is oxidized to nitrate by bacteria in the nitrification process. This microbial facilitated redox reaction consumes oxygen at a ratio of 4.5 mg of O2 to every 1 mg of NH4+, thus rapidly depleting available oxygen for aquatic organism respiration. At higher pH (above 7.5 or 8.0), the $NH_4^+ \Leftrightarrow NH_3$ equilibrium reaction begins to favor ammonia, which is directly toxic to aquatic life because it may be taken up through membranes, and interferes with cell metabolism. Higher temperatures also favor the uptake of ammonia (movement across membranes, e.g. gills) by aquatic organisms causing the Chronic Criteria (CCC) for aquatic organisms are lowered as temperature increases. Ammonia is low in all streams in NCR, which is good because higher levels are associated with sewage spills and septic leaks in developed areas.

NCRN utilizes Hach Nitrogen – Ammonia Method 10023 (Salicylate Method) to determine the concentration of ammonia in a sample.

Nitrogen-Nitrate

Nitrate in surface water is considered a nutrient and may occur in dissolved or particulate form resulting from inorganic sources. The dissolved, inorganic forms of nitrogen are most available for biological uptake and chemical transformation . Nitrate above 2.0 mg/L can lead to eutrophication of water bodies.

NCRN utilizes Hach Nitrate Method 8039 (Cadmium Reduction Method) to determine the concentration of nitrate in the samples.

pH

The pH of water directly affects physiological functions of plants and animals, and is, therefore, an important indicator of the health of a water system (NPS-WRD 2002; Stednick and Gilbert 1998; USGS 1980). pH is measured to determine the acid/base characteristics of water and is controlled by interrelated chemical reactions that produce or consume hydrogen ions (Hem 1989). The term pH literally means "power of hydrogen." The more hydrogen ions that are available for reaction, the lower the pH. The concentration of these ions is measured on a log scale that most commonly ranges from 0 (acid) to 14 (base / alkaline), so each pH unit increase represents a 10X decrease in hydrogen ion concentration. Pure water has a pH of 7 (neutral), which means that it is equally able to accept or donate hydrogen ions. At pH < 7, (acid) hydrogen ions are more readily donated (Hem 1989, Stednick and Gilbert 1998).

Generally, dissolution of carbon dioxide to carbonic acid is the most important acidifying factor in extremely fresh natural waters to affect pH (~ pH of 6) in the absence of some other site-specific conditions. However, most natural waters are slightly basic (~pH of 8) due to the presence of carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-). In freshwater, the $CO_2 \Leftrightarrow HCO_3^- \Leftrightarrow CO_3^{2-}$ equilibrium serves as the primary buffering mechanism. In natural waters, carbonic acid is the main source of hydrogen ions, resulting in a pH of 5.7. Rain-water normally is acid because of its carbon dioxide content and naturally occurring sulfate. Normally these acids are neutralized as rain-water passes through the soil. In catchments of hard rocks, little buffering capacity, and high surface water (s opposed to groundwater) inputs, stream water will be acid even if pollution is absent. Organic acids also contribute to low pH values. Industrial activity has contributed to acid precipitation in many areas. Strong inorganic acids H2SO4 and HNO3, formed in the atmosphere from oxides of sulfur and nitrogen, have seriously lowered surface water pH in large areas of Europe and North America, especially in granitic drainages with poor buffering capacity.

pH is important in the toxicity and solubility of many constituents. The ideal natural range of pH in surface waters is 6.0 to 8.5. Freshwaters can vary widely in acidity and alkalinity due to natural causes as well as anthropogenic inputs. Extreme pH values, generally those much below 5 or above 9, are harmful to most organisms, and the buffering capacity of water is critical to life. Estimating the toxicity of ammonia, aluminum, and some other contaminants requires accurate pH values. Increases or decreases in pH from their normal range into extreme ranges can result in severe harm to aquatic life (Hem 1989). Changes in pH affect the dissociation of weak acids or bases, which in turn affects the toxicity of many compounds. For example, hydrogen cyanide toxicity to fish increases with lowered pH; rapid increases in pH increase NH3 concentrations; and the solubilities of metal compounds are affected by pH. Metals mobility is also enhanced by low pH and that can play a significant factor in impacts to water bodies located in areas contaminated by heavy metals (e.g. mining). The permissible range of pH for fish depends upon many other factors such as temperature, DO, and the content of various anions and cations. The importance of pH as a parameter for monitoring is reflected by potential impacts to the life cycle stages of aquatic macroinvertebrates and certain salmonids that can be adversely affected when pH levels above 9.0 or below 6.5 occur. Temporal causes of variation of pH can range from primary production by fauna and flora (diurnal and seasonal) to fractionation during snowmelt, changes in runoff processes, and changes in atmospheric deposition (monthly and/or seasonal) (MacDonald et. al., 1991).

NCRN utilizes a YSI handheld meter model number 63 to measure the pH at each site.

Phosphorus

Phosphorus (PO_4) is frequently a limiting nutrient in aquatic systems. A minor increase in phosphorous concentration can significantly affect water quality by changing the population and community dynamics of algae and diatoms leading to eutrophication (Allan 1995). Phosphorus is singled out as an especially important indicator in the Heinz Center Report (2002) on the state of nation's ecosystems. Sources of phosphorous include sediments, fertilizer application (e.g. irrigation return flow), soaps, and detergents. 0.1 mg/L PO4 is the published threshold for eutrophication of flowing surface waters.

NCRN utilizes Hach Total Phosphorus Method 8190 (Acid Persulfate Digestion Method) to convert organic and condensed inorganic phosphates into orthophosphates. Hach Phosphorus – Reactive Orthophosphate Method 8178 (Amino Acid Method) is then employed to determine the total phosphorus concentrations for each sample.

Specific Conductance

Specific conductance is the electrical conductivity of the aqueous solution and is directly related to concentration of ionic species. Conductivity is a measure of the capacity of water to conduct an electrical current and is a function of the types and quantities of dissolved, electrically charged substances (ions) in water (Radtke, Davis, and Wilde, 1998). The conductivity of solutions of ionic species is highly dependent on temperature and may change as much as 3% for each 1°C change. Thus a significant apparent change in conductivity may simply be a function of the water body's diurnal or seasonal temperature change. In addition, the temperature correction coefficient itself varies with the charge and abundance of the ionic species present (e.g. Na + Vs Ca ++) so no universally applied algorithm will be exact. A raw conductivity value is not temperature compensated making it difficult to compare measurements of the same or different water bodies when not at the same temperature (e.g. conducting trend analysis over time). When the raw conductivity measurement of a substance is normalized to unit length and unit cross-section at a specified temperature (e.g. a compensation temperature of 25 °C), it is called specific conductance (NPS-WRD 2002; Stednick and Gilbert 1998; USGS 1980). Specific conductance is dependent upon the types and quantities of dissolved substances and is a good indication of total dissolved solids (TDS) and total ion concentration.

The electrical conductivity of a water body has little or no direct effect on aquatic life but because it is essentially due to the sum of all ionic species, its change (increase) may be detrimental if the particular ionic species or groups of ionic species (e.g. specific salts) causing the change is toxic to aquatic life. Small quantities of mineral salts are usually contained in natural inland waters, but in waters polluted by brines and various chemical wastes, salt concentrations may rise to levels harmful to living organisms due to the increase in osmotic pressure. Salinity is often expressed as specific electrical conductance in studies of waters used for irrigation and fish production. Collectively, all substances in solution exert osmotic pressure on the organisms living in it, which in turn adapt to the condition imposed upon the water by its dissolved constituents. With excessive salts in solution, osmotic pressure becomes so high that water may be drawn from gills and other delicate external organs resulting in cell damage or death of the organism (NPS-WRD 2002; Stednick and Gilbert 1998; USGS 1980). The Maryland

Biological Stream Survey has found that fish exhibit stress at specific conductances greater than 400 µS/cm.

Specific conductance is useful in estimating the concentration of dissolved solids in water. Electric current is carried by dissolved inorganic solids such as chloride, carbonate, nitrate, sulfate and phosphate anions (negatively charged particles), as well as sodium, calcium, magnesium, potassium, iron and aluminum cations (positively charged particles). Common sources of pollution that can affect specific conductance are deicing salts, dust reducing compounds, agriculture (primarily from the liming of fields) and acid mine drainage (AMD) associated with mining operations (NPS-WRD 2002; Stednick and Gilbert 1998; USGS 1980). Organic materials such as oils, phenols, alcohols and sugars do not carry electric current.

NCRN averages multiple measurements displayed by both YSI handheld meters, model numbers 63 and 85, to determine the specific conductance at each site.

Discussion of Findings

Each park will be discussed individually. The Region's water quality as a whole is reviewed in the Executive Summary. Parks are grouped by physiographic regions, geologic strata, or watersheds, as appropriate. The National Capital Region crosses four physiographic regions (see figure 1 for park locations across the regions). Baseline water conditions are influenced by the differences in topography, geology and soils among these regions. The Provinces also differ greatly in the spatial pattern and intensity of land use, which in turn influences environmental stresses: the commercially oriented Piedmont and Atlantic Coastal Plain facing the sea contain the great megalopolis from Portland, ME to Richmond, VA. The Appalachian Highlands and Allegheny Plateau, contain part of the great American manufacturing belt. The Province's are described below. Individual Park summaries begin on page 34.

Ridge & Valley

The landscape of the Ridge and Valley physiographic province is characterized by long, parallel ridges interspersed with valleys that formed where resistant sandstone ridges border erodible carbonate formations in the valleys. Areas dominated by carbonate formations exhibit karst topography - landscapes dotted by sinkholes, caves, and caverns. Fertile limestone soils in the Ridge and Valley Province are ideal for agriculture, which contributes much pollution, while other areas are predominantly forested. Within the NCRN, the following parks are completely or partially located within the Ridge and Valley physiographic province: ANTI, CATO, CHOH, and HAFE.

The Ridge and Valley extends from the St. Lawrence River southward to Alabama. It is arranged in a northeast to southwest progression that includes the accompanying Great Valley subprovince (Shepherdstown to Fort Frederick State Park), which is characterized by broad valleys with low to moderate slopes underlain by carbonate rocks (Fenneman 1938; Thornbury 1965). The rocks of the Ridge and Valley have been intensely folded, faulted and eroded producing long narrow northeast tending ridges capped by resistant sandstone and valleys underlain by less-resistant, more permeable shale and carbonate rocks. Fracturing and dissolution have produced substantial permeability in the upper 300 feet. Groundwater is restricted by the parallel ridges, flowing from ridge to adjacent valley until it either discharges to local streams or is intercepted and directed down valley by a layer of rocks with well-developed permeability (Blomquist 1996).

The valleys of The Great Valley are generally of two types. Those underlain by carbonate rocks are nutrient rich and therefore good for agriculture and the streams tend to be colder and flow all year. Those underlain by shale are less productive and more irregular with greater densities of streams that tend to lack flow during dry periods (MD DNR 1999). Karst topography is characteristic of the carbonate portion of the Great Valley. Karst is a three dimensional landscape developed on and in soluble rock units such as dolomite (calcium and magnesium carbonate) or limestone (calcium carbonate). Through time, precipitation and groundwater drain through cracks and crevices in the carbonate bedrock, slowly dissolving the rock to form an underground network of conduits that often produce karstic features. In such places there may be little or no surface runoff making these areas very susceptible to water pollution, since it passes almost directly into the groundwater reservoir. Acidic precipitation increases the dissolution, which increases the speed of flow from surface to ground, and increases the spread of the pollution (White 1988). The karst features can be contiguous and extensive, allowing pollution to travel long distances (Blomquist 1996). The limestone/dolomite bedrock area underlying the Great Valley runs throughout Washington County and is contiguous with areas under Harper's Ferry National Historic Site, Antietam National Battlefield and Chesapeake and Ohio Canal National Historic Site.

Blue Ridge

The Blue Ridge Province is a rugged region with steep slopes, narrow ridges and broad mountains with relatively high relief located on the eastern edge of the Appalachian Mountains. Ancient igneous and metamorphic rocks were uplifted to form the steep terrain. Fast flowing streams have resulted in the northern section of the Blue Ridge Mountains narrowing into a thin band of steep ridges, the eastern scarp (line of cliffs) of the Blue Ridge, with elevations from 1000 to 5700 feet. The province is mostly forested with cool clear streams, steeply sloped over mostly sandstone and shale, and is characterized by steep terrain covered by thin/shallow soils, resulting in rapid runoff and low ground water recharge rates. Consequently, the water table ranges from land surface at the springs and streams to 70 feet below the land surface on ridges. Within the NCRN, CATO, a small section of the CHOH, and a portion of HAFE are located within the Blue Ridge Province.

Within these ridges, Catoctin Mountain is a discontinuous ridge that extends from near the Pennsylvania/Maryland border to the Potomac River at Point of Rocks, Maryland. Within CATO, rock units are highly fractured and folded and range from quartzite along the southeast edge, phyllite and conglomerate in the southeast section and metarhyolite and metabasalt in the northwest (Huth and Wright 1981). These rocks are resistant to erosion and dissolution. Slopes in the park are generally between 10% and 20%, but occur up to 60% (Trombley and Zynjuk 1988).

Groundwater is stored primarily in and moves through secondary openings in the crystalline granitic gneiss which are not as likely as those in sedimentary rock to be enlarged by dissolution. Aquifers within the Blue Ridge and Piedmont provinces are characteristically small. The springs that occur in the region typically have low flow rates and many are seasonal (Otten and Hilleary, 1985). The high topographic position affects the ecological characteristics – because of the relief and narrowness most of the streams that drain the Blue Ridge are headwater tributaries of larger streams in the Great Valley or Piedmont. In Maryland the Blue Ridge forms the major divide within the basin – all stream-flow west of Blue Ridge is passes through a gap at Harper's Ferry to the Great Valley. Stream-flow on the east flows to the Piedmont (Blomquist 1996). Streams are mostly rocky and may meander through wide floodplains or cascade down steep mountainsides. Some, like Owens Creek, even course through wetland glades that resemble the Coastal Plain (MD DNR 1999)

Discharge from the groundwater flow system is mainly to nearby streams adjacent to areas of recharge. Groundwater comprises 55%-57% of annual stream flow. Overland flow is mostly subsurface through a thick 30-40% loamy soil (Means 1995; Trombley and Zynjuk 1988). Most precipitation is collected and absorbed by the very loamy and rocky surface soils. The result is that the water drains into streams as subsurface runoff. Of the 44 inches of precipitation that fall annually, 57% will leave the park as stream water. In the case of Big Hunting Creek this source of water contributes about 40% of the total stream flow (USGS 1985). This subsurface flow is fairly steady but is affected by fluctuations in precipitation. For example during particularly wet periods upon saturation of the soil, many small intermittent creeks become active delivering the excess water above ground instead of through the soil. Access to the aquifer is available through springs and wells, which supply the parks tap water (Trombley and Zynjuk 1988).

Piedmont

The Piedmont is the least mountainous part of the Appalachian Highlands and its' rock is soft compared to the mountains. The Piedmont is characterized by a gently rolling topography of deeply weathered bedrock, with some solid outcrop. Rocks are strongly weathered in the Piedmont's humid climate and bedrock is generally buried under a thick (2-20m) blanket of saprolite (typically soft clay-rich decomposed rock formed in place by chemical weathering of igneous, sedimentary or metamorphic rocks). Outcrops are commonly restricted to stream valleys where saprolite has been removed by erosion. A variety of igneous and metamorphic rocks make up the bedrock of the Piedmont province. Most streams are of moderate slope with rock or bedrock bottoms. At a large scale the drainage within the Piedmont is remarkably similar to the Coastal Plain. The east and west are underlain by resistant crystalline rocks with the same groundwater characteristics as the Blue Ridge (Blomquist 1996; Fenneman 1938; MD DNR 1999; Thornbury 1965; William & Mary, 2000). The Triassic Basin subregion (central section of the Piedmont) is characterized by areas of low relief and large expanses of shale and red sedimentary sandstone (MD DNR 1999). Groundwater is stored and transmitted in primary and secondary openings and groundwater flow is locally interrupted by intrusive and extrusive igneous rocks (Blomquist 1996). The subregion is particularly conducive to the formation of wetlands, which differ from other wetlands in the depth of their sediments and soils and their hydrologic patterns.

The Fall Line marks a transitional zone where the softer/erosion-prone sedimentary rock of the Coastal Plain to the east, intersects the more resilient metamorphic rock of the Piedmont Plateau to the west. The transition zone forms an area of waterfalls and rapids that act as a barrier to dispersal for many aquatic and terrestrial organisms. This often creates localities of high biological diversity such as at the Potomac Gorge (Cohn 1994, NPS and TNC 2001). Soils in the Piedmont Plateau are highly weathered and generally well drained. A majority of parks of the NCRN are located completely or partially within the Piedmont Plateau Province, including: CHOH, GWMP, MANA, MONO, PRWI, ROCR, and WOTR.

Streams that cross this division of older, harder upland rocks of the Piedmont to loose, unconsolidated younger rocks of the Coastal Plain tend to have falls or rapids in their channels (Atwood 1940, Thornbury 1965). The Falls more commonly lie a few miles inside the Piedmont Region, for example the Potomac River is tidal 10 miles upstream of the Fall Line. South of the Potomac, the Piedmont is not strongly marked (Fenneman 1938; Thornbury 1965). Washington, DC, Philadelphia, Baltimore, Richmond, Raleigh, Columbia, and Macon are fall-line cities. Fall Line cities are supplied chiefly from surface water sources of the Appalachian Highlands. Rivers coming off the Piedmont drop to the lower elevations in waterfalls. The fall line is an imaginary line connecting the waterfalls. From the Fall Line, elevations rise steadily westward over hilly terrain to 1100 and 1200 feet (335 and 365 meters) near the Blue Ridge boundary (Fenneman 1938; Thornbury 1965).

Coastal Plain
The Atlantic Coast is a broad terraced plain rising inland to an elevation less than 150 m and characterized by sandy soil and low gradient topography, slow-flowing streams (Hunt 1967, William and Mary 2000). The province was formed by sediments eroding from the Atlantic Highland areas to the west, fluctuating sea levels, and the continual erosive action of waves along the coastline. The unconsolidated surficial deposits include: soft sand and gravel alluvium in the floodplains of rivers; sand and gravel on uplands; beach and dune sand, peat, muck, and marsh deposits along coasts which have eroded from the Appalachian Mountains and carried eastward. Coastal Plain surface soils are commonly sandy or sandy-loams that are well drained, low in organic carbon content, and contain soluble elements such as iron, calcium, and magnesium. In a few areas these deposits are firmly consolidated into limestone or sandstone. Most of these deposits exist as unconsolidated sand, gravel, clay, or marl with localized deposits of phosphorus rich limestone. The underlying sediments range in thickness from 100s of feet at the Fall Line to 1000s of feet at the shelf (Atwood 1990; Fenneman 1938; Hunt 1967; MD DNR 1999; Thornbury 1965; William and Mary 2000). Large streams and rivers in the Coastal Plain province are often influenced by tides. Within the NCRN, the following parks are located (all or in part) within the Coastal Plain Province: CHOH, GWMP, NACE, PRWI, and ROCR.

Embayment of the Mid-Atlantic Region means that there is not much fresh surface water in the Coastal Plain because brackish water extends up the rivers to the Fall Line. Streams have shallow gradients and discharge to tidal creeks or wetlands which have considerable effect on streamflow, morphology and water quality. Groundwater resides in and moves through interstices between individual mineral grains rather than rock fractures and secondary openings like most of the basin. The uppermost sediment mantling the Plain forms generally unconfined aquifers characterized by local groundwater flow systems and short flow paths. These aquifers can yield large quantities of groundwater, upon which many communities rely. Groundwater wells tapping aquifers yield a good supply of water but below 1000 feet in some areas freshwater changes to salt and overdraw must be avoided (Blomquist 1996; Hunt 1968). This is already a problem along the urban areas of the Chesapeake Bay.

Streams have shallow gradients and discharge to tidal creeks or wetlands which have considerable effect on streamflow, morphology and water quality. Groundwater resides in and moves through interstices between individual mineral grains rather than rock fractures and secondary openings like most of the basin. The uppermost sediment mantling the Plain forms generally unconfined aquifers characterized by local groundwater flow systems and short flow paths. These aquifers can yield large quantities of groundwater, upon which many communities rely. Groundwater wells tapping aquifers yield a good supply of water but below 1000 feet in some areas freshwater changes to salt and overdraw must be avoided (Blomquist 1996; Hunt 1968). This is already a problem along the urban areas of the Chesapeake Bay.

Condition Assessment and Significance Tables
The data collected in 2005- 2006 was analyzed to determine if each stream meets water quality standards. As only one year of data is available, no attempt was made to determine seasonal effects or long term trends. Data for each stream was analyzed separately and each sampling event was considered to be independent. Two assessments were made for each stream.

The first assessment compared the water quality parameter values of each stream to published standard s using 1-sample t-tests as illustrated in Figure 2 below. The number for each water quality standard indicates the % of the measurements that did not meet the standard. The color of the circle indicates the comparison between the mean value and the standard based on the t-test. Solid green circles indicate the mean value is significantly better than the standard, whereas the open green circles indicate the mean meets the standard, but that this result is not significant. Solid red circles indicate the mean value is significantly worse that the standard, whereas open red circles indicate the mean value does not meet the standard but that this is not significant. Grey circle indicate insufficient data to perform the test. Gray and green circle indicates that the mean value does not exceed the threshold but that insufficient data exist to perform significance testing. Numbers in the circles indicate the percentage of measurements that exceed the threshold.

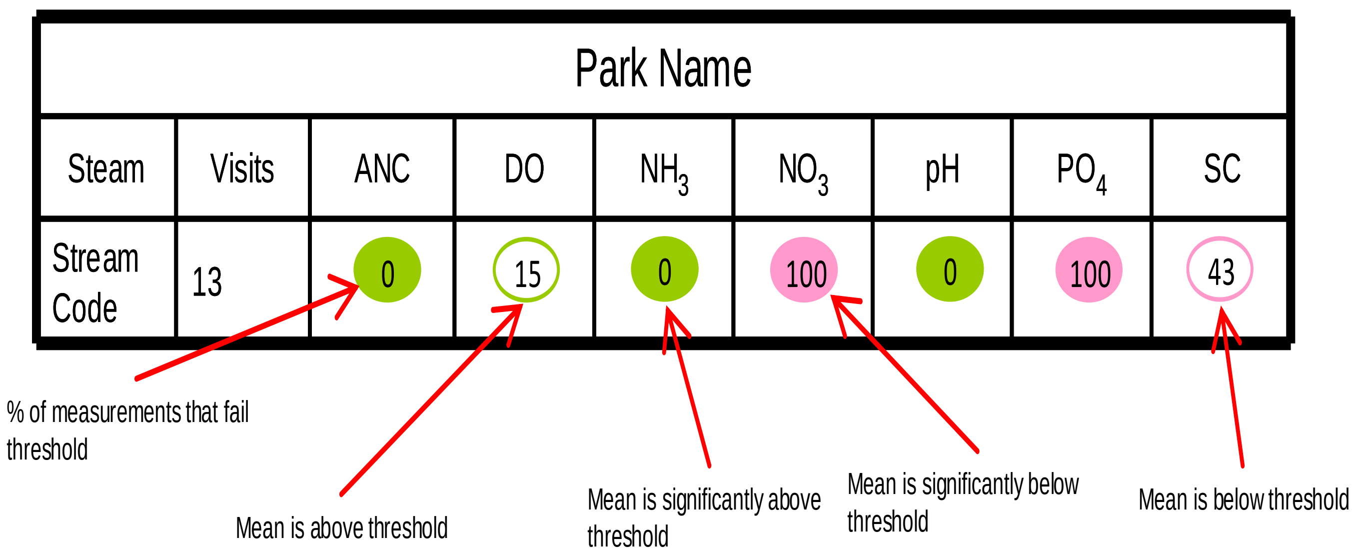

Figure 2: Example of Condition Assessment and Significance

A second analysis evaluated the minimum detectable difference (MDD) to be expected from the monitoring. The MDD is the smallest differences between a water quality standard and the water quality in a stream for which we can expect to show a significant difference. The MDDs were determined using a power. The results of this analysis are presented in the time series graphs of the data. These graphs indicate the value of the water quality parameter for each sampling event, the mean value and the threshold for that parameter. Also plotted are the minimum detectable differences, assuming twelve samples, a p-value of 0.05, and a power of 0.80. If the water quality standard is outside of the area of between the dotted lines, the monitoring has at least an 80% chance of finding this difference between the mean and the standard significant, based on data from twelve samples over a single year.

Antietam National Battlefield (ANTI)

ANTI is a 3,256-acre park located within the Ridge and Valley Physiographic Province in Washington County, Maryland. Streams, wetlands, and groundwater are counted among some of the park's most important natural resources. Numerous seeps and springs occur throughout the landscape. Much of the park today is maintained to replicate the Civil War viewshed during the Battle of Antietam. As such, the landscape of the park is mostly agricultural in nature.

The park is located within the Antietam Creek drainage of the Conococheague-Opequon watershed (USGS hydrologic unit 02070004). Antietam Creek is a shallow, slow-flowing creek meandering through farmland. The west branch of the creek originates in south central Pennsylvania, north of the town of Waynesboro, MD. Sixty percent of the Antietam Creek drainage basin is within Washington County, Maryland (U.S. Army Corps of Engineers, 1972). Land use within this basin is 69 percent agriculture, 24 percent forest and 7 percent urban (U.S. Geological Survey 1995). Impacts to the stream are due to agricultural practices and activities in and around Waynesboro, Pennsylvania and Hagerstown, Maryland, the two principal cities in the drainage area.

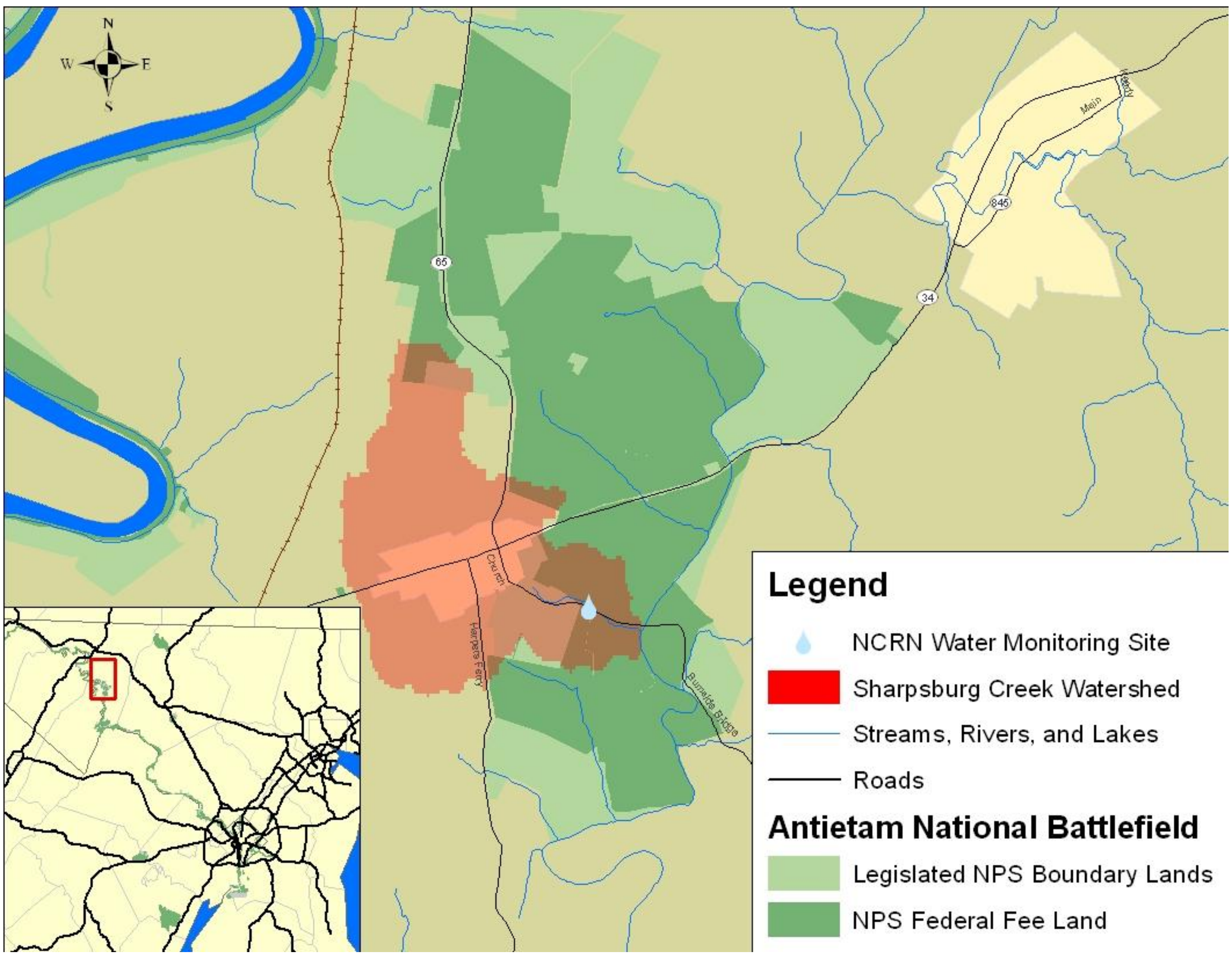

Figure 3: Relationship of the Sharpsburg Creek monitoring site to the watershed and the park boundary

The park is located in karst topography, a landscape of distinctive dissolution patterns often marked by underground drainages. These are areas where the bedrock has a soluble layer of carbonate rock such as limestone. In such places there may be little or no surface drainage. All water runs underground. These areas are very susceptible to water pollution, since it passes almost directly into the groundwater reservoir. Acidic precipitation increases the dissolution (White 1988). The limestone/dolomite bedrock area underlying the park runs throughout Washington County and is contiguous with areas under Harper's Ferry National Historic Site and Chesapeake and Ohio Canal National Historic Site. The park has collected its own water quality data at 7 sites including groundwater seeps and springs for several years. They are also currently partnering with Earl Greene of the USGS on a quantity and quality survey of the groundwater shed of Mumma Spring. All of the available data will be analyzed and presented for the 2007 report on Water Chemistry and Quantity.

Within ANTI, the I&M Water Quality and Quantity program monitors a single site, along Sharpsburg Creek. The site is located just downstream of the Burnside Bridge Road crossing, at the Sherrick Farm. Sharpsburg Creek is a tributary of Antietam Creek and originates in the Town of Sharpsburg. Runoff from the town of Sharpsburg serves as a primary stressor to the creek, as does a couple of livestock pastures located along side it.

Table 4: Date range, number of site visits, and data range for the information covered in this report.

Sharpsburg Creek					
Characteristic	**Units**	**Period of Record**	**Count**	**Min.**	**Max.**
ANC	μeq/L	6/2/2005 - 8/14/2006	13	2100	4420
DO (mg/L)	mg/l	5/23/2005 - 8/14/2006	14	1.98	11.6
Nitrate	mg/l	5/23/2005 - 8/14/2006	14	4.6	14.3
Nitrogen, Ammonia	mg/l	5/23/2005 - 8/14/2006	14	0	0.06
pH	None	5/23/2005 - 8/14/2006	14	7.67	8.36
Phosphorus	mg/l	5/23/2005 - 8/14/2006	14	0.22	2.03
Specific conductance	μS/cm	5/23/2005 - 8/14/2006	14	0	656

Table 5: Condition assessment and significance for site visits to Sharpsburg Creek 2005 – 2006.

Stream	ANC	DO	NH_3	NO_3	pH	PO_4	SC
Sharpsburg Creek	0	15	0	100	0	100	92

Much of the park is maintained as agriculture to replicate the historical Civil War viewshed. The agriculture lease agreements allow for fertilizer and pesticide applications and some fields are leased for livestock grazing. These are probably among the sources of the nitrate and phosphorus. Other sources include acid rain and atmospheric deposition as well as background levels in groundwater.

The higher pH and acid neutralizing capacity of Sharpsburg Creek are due to dissolution of the limestone and dolomite bedrock (see figure 4). This may also contribute to the higher specific conductance, though fertilizers, pesticides, and livestock runoff may also contribute. Limestone ($CaCO_3$) and dolomite ($CaMg(CO_3)^2$) are ionic salts that dissociate in pure water to their constituent ions: Ca^{2+} and CO_3^{2-}; Ca^{2+} + Mg^{2+} + 2 CO_3^{2-} Groundwater in karst areas can also contain sulfate ions from gypsum beds and weathered sulfite materials, chlorides from deeper circulating ground water and seawater mining, sodium, potassium, dissolved oxygen. This increase in dissolved ions also increases the specific conductance (White 1988).

The errant specific conductance value of zero, in May 2005, may be the result of heavy rainfall that occurred prior to sampling and may have diluted groundwater contribution. This value may also be the result of equipment failure or operator error.

Dissolved Oxygen is Sharpsburg Creek tends to decrease and nutrients increase, an expected trend, because increased nutrients facilitate algal growth increasing oxygen demand especially during decomposition. The lowest dissolved oxygen measurements occurred in spring 2006 before full leaf out when Sharpsburg Creek still received full sunlight. Notice in figure 5, initially there are increases in dissolved oxygen, presumably from algae production. Observation of algae percent cover will be included in the 2007 report.

These measures constitute a snapshot of stream conditions in time and space, and are not representative of quality over a 24 hour period. All of these measures are influenced to a certain degree by biological activity which follows diurnal and seasonal patterns of temperature and sunlight. Continuous data for dissolved oxygen, pH, temperature, specific conductance will be included in the 2007 report. There is not yet enough data to identify seasonal patterns or trends.

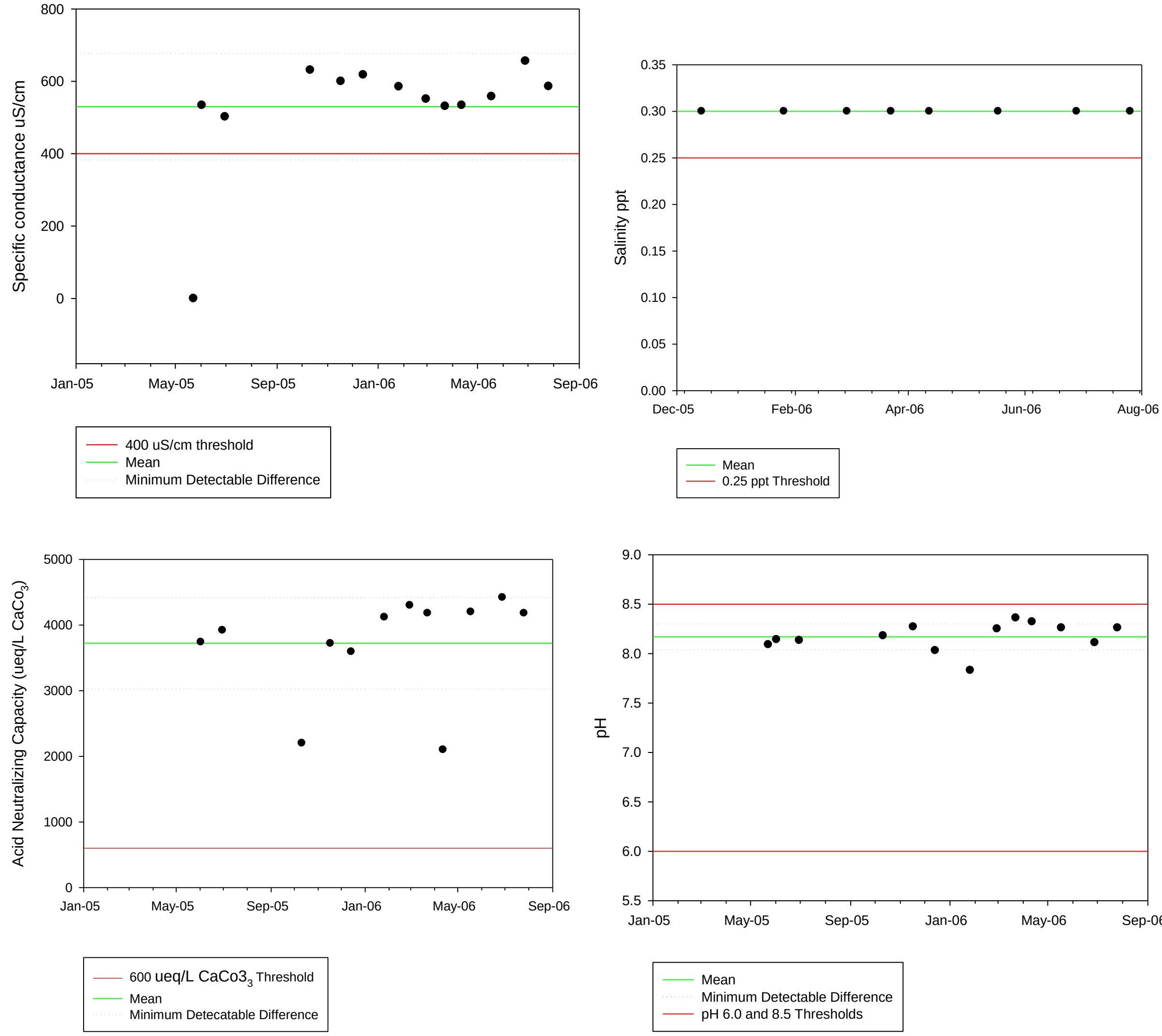

Figure 4: Specific Conductance, salinity, ANC, and pH in Sharpsburg Creek 2005-2006.

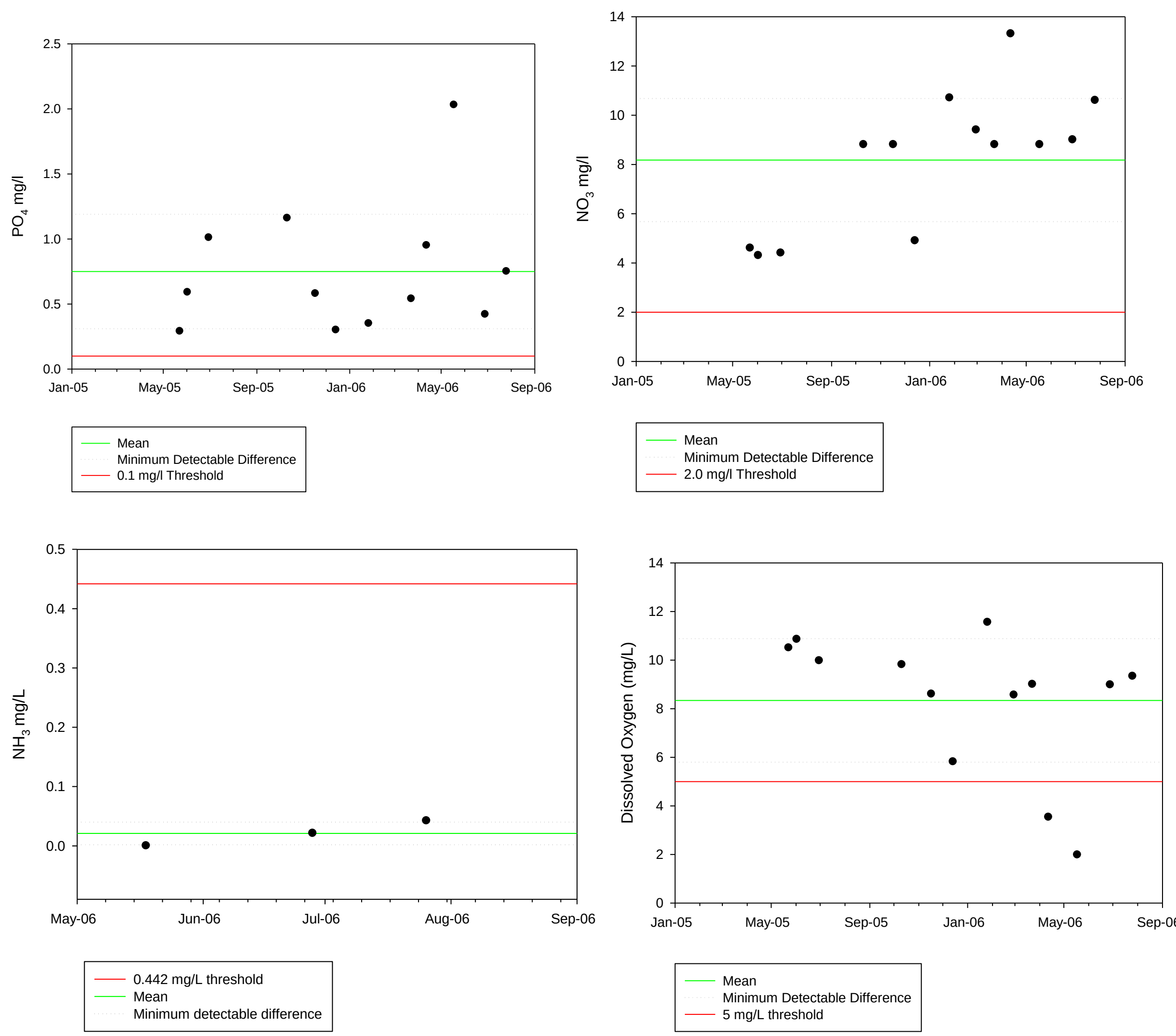

Figure 5: Nutrients and Dissolved Oxygen in Sharpsburg Creek 2005-2006

Harpers Ferry National Historical Site (HAFE)
HAFE is a 4,000-acre park located within the Ridge and Valley Physiographic Province in Jefferson County, West Virginia, and the Blue Ridge Physiographic Province in Washington County, Maryland and Loudon County, Virginia; at the confluence of the Shenandoah and Potomac rivers. A few tributaries to both the Potomac and the Shenandoah are found throughout the park, though the two rivers themselves are not considered as part of the park. The park is maintained as a replicate of several periods of American history, including early manufacturing, slavery, the Civil War, and early integration.

The park is located at the confluence of the Potomac and Shendandoah Rivers. Elk Run is the major water supply for the town and a 500-foot section runs through the park before it empties into the Potomac River. A short portion of Piney Run crosses the park before it also enters the Potomac. The only stream with any appreciable length on park property that would be affected by park management is Flowing Springs, which winds for about one mile along the park before it enters the Shenandoah. NCRN samples a site downstream of the Millville Quarry, as the stream exits park property. Impacts to these smaller watersheds include development, de-icing operations, agricultural land use, and nearby septic systems.

The western section of the park containing Flowing Spring, in Jefferson County, WV is underlain by karst topography similar to that found in ANTI. The limestone/dolomite bedrock area underlying the park continues north into Washington County, MD and is contiguous with areas under ANTI and CHOH.

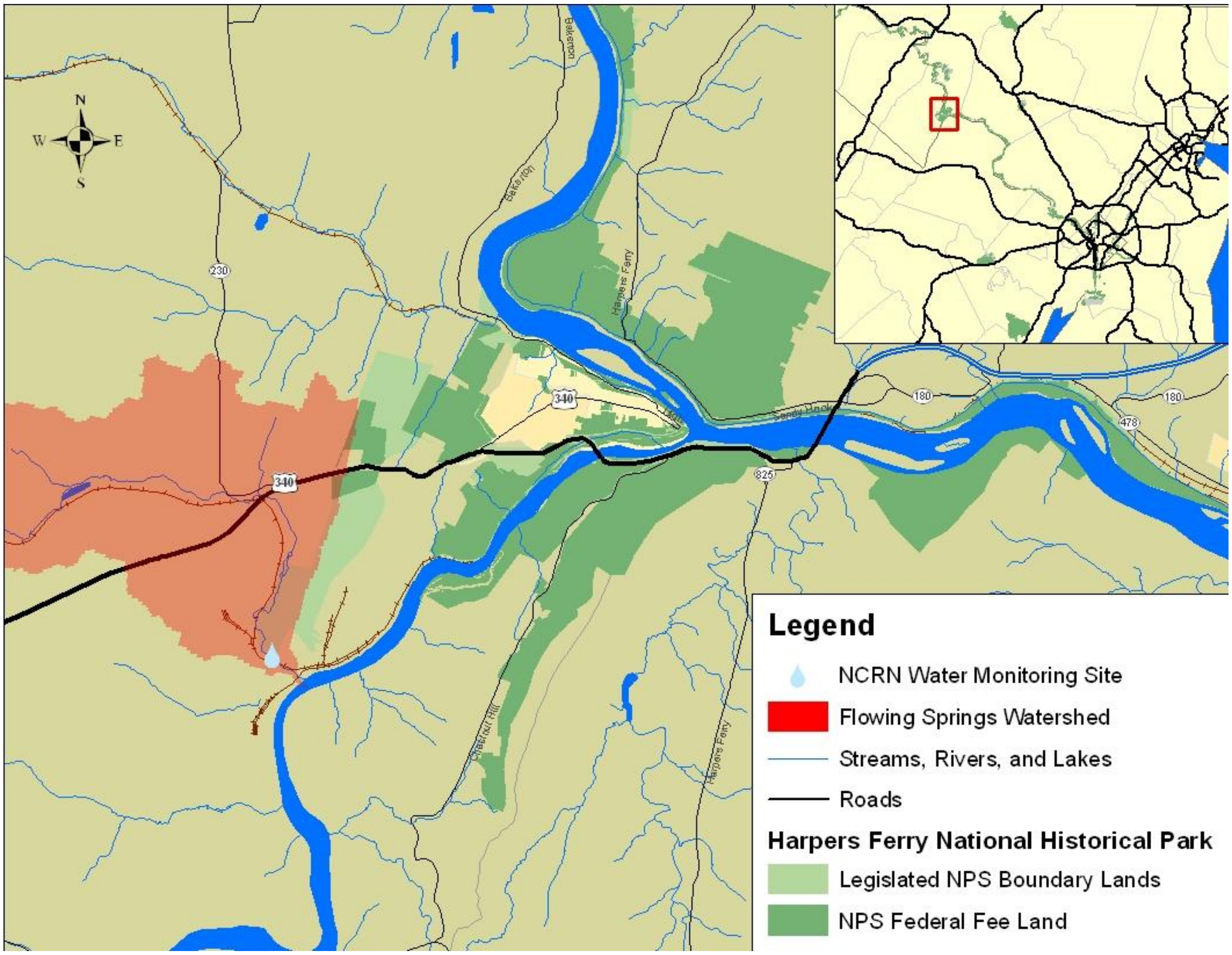

Figure 6: Relationship of the Flowing Springs monitoring site to the watershed and the park boundary

Table 6: Date range, number of site visits, and data range for the information covered in this report.

Characteristic	Units	Period of Record	Count	Min.	Max.
Flowing Springs Run					
ANC	µeq/L	6/2/2005 - 8/14/2006	13	2800	5040
DO (mg/L)	mg/l	6/2/2005 - 8/14/2006	13	2.1	13.1
Nitrate	mg/l	6/2/2005 - 8/14/2006	13	0.3	9.3
Nitrogen, Ammonia	mg/l	6/2/2005 - 8/14/2006	13	0.04	0.2
pH	None	6/2/2005 - 8/14/2006	13	7.67	8.59
Phosphorus	mg/l	6/2/2005 - 8/14/2006	13	0.26	1.05
Specific conductance	µS/cm	6/2/2005 - 8/14/2006	13	374	1029

Table 7: Condition assessment and significance for site visits to Flowing Springs 2005 – 2006.

Stream	ANC	DO	NH_3	NO_3	pH	PO_4	SC
Flowing Springs Run	0	23	0	92	15	100	92

The higher pH and acid neutralizing capacity of Flowing Spring Run are due to dissolution of the limestone and dolomite bedrock (see figure 7). This process may be natural, or due in direct relation to the crushed stone quarry located immediately upstream of the site. This may also contribute to the higher specific conductance, though fertilizers, pesticides, and livestock runoff may also contribute.

DO in Flowing Springs Run tends to decrease as nutrients increase, which is expected because increases in nutrients facilitates growth spurts of algae, which can consume more oxygen that they produce during decomposition. The lowest dissolved oxygen measurements occurred in spring 2006 before full leaf out when Flowing Springs Run still received full sunlight. Notice in figure 7, initially there are increases in dissolved oxygen, presumably from algae production. Observation of algae percent cover will be included in the 2007 report.

These measures constitute a snap shot of stream conditions in time and space, and are not representative of quality over a 24 hour period. All of these measures are influenced to a certain degree by biological activity which follows diurnal and seasonal patterns of temperature and sunlight. There is not yet enough data to identify seasonal patterns or trends.

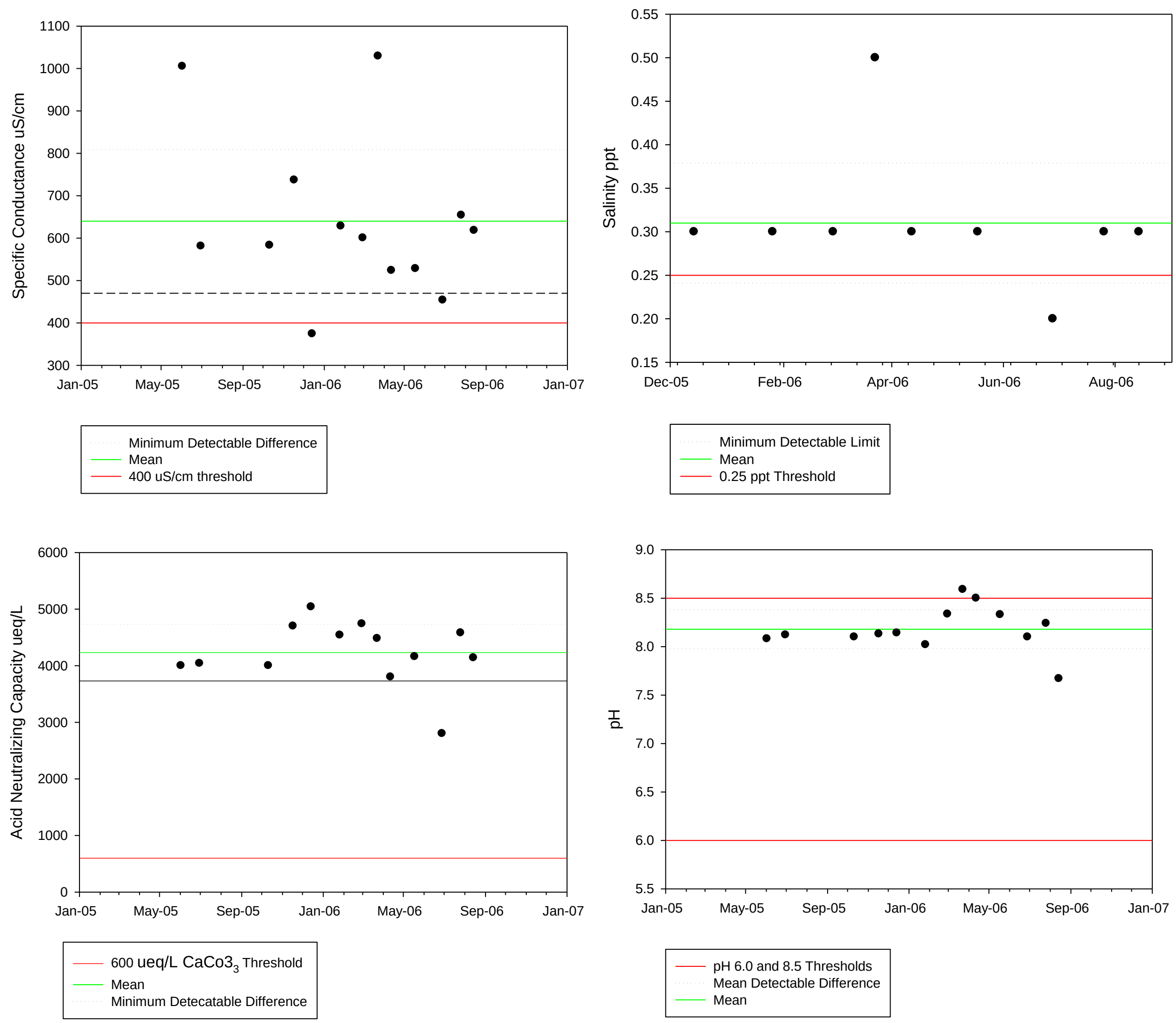

Figure 7: Specific Conductance, salinity, ANC, and pH in Flowing Springs Creek 2005-2006

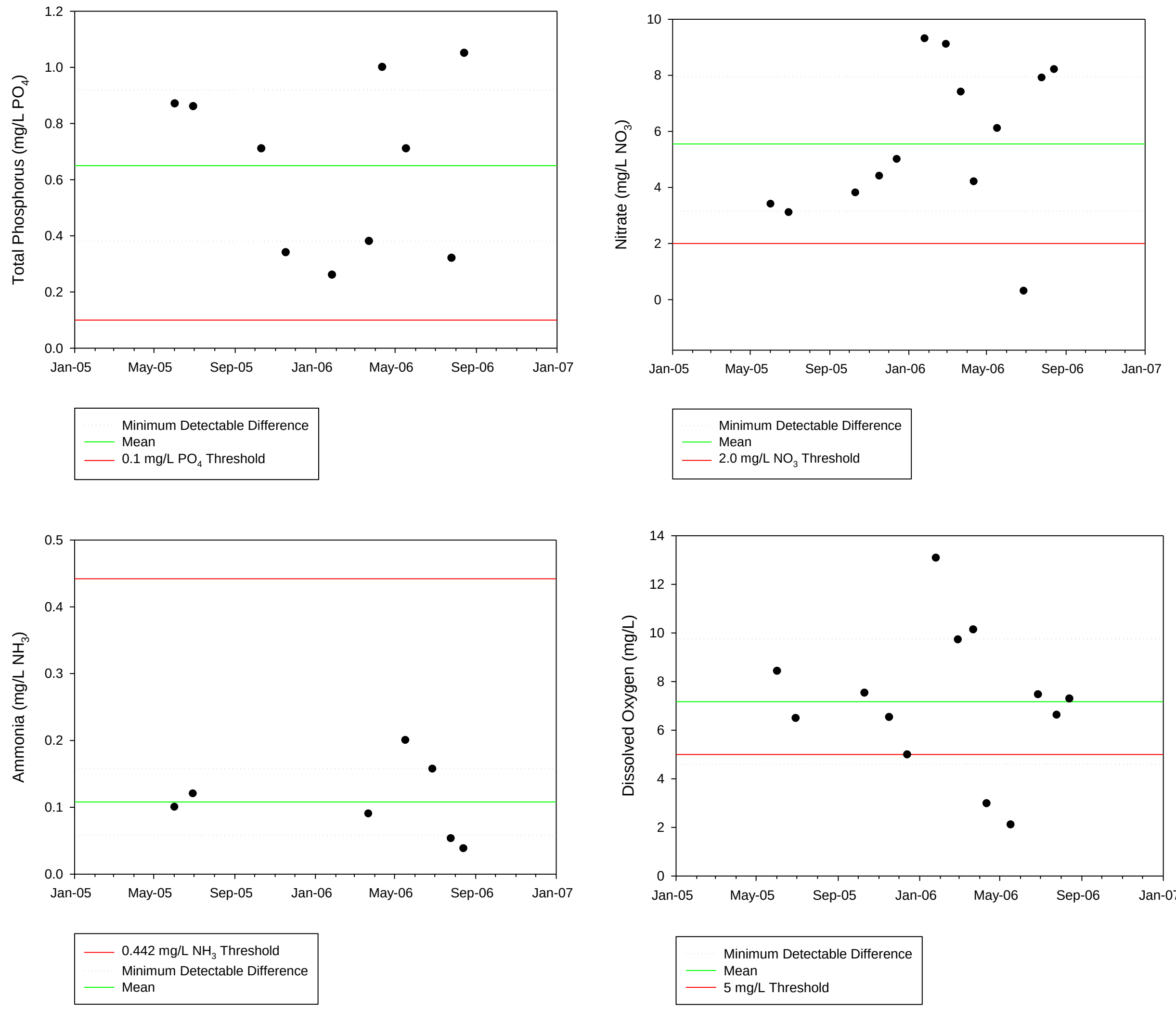

Figure 8: Nutrients and Dissolved Oxygen in Flowing Springs Creek 2005-2006

Monocacy National Battlefield (MONO)
MONO is a 1,647-acre park located within the Piedmont Physiographic Province of Frederick County, Maryland. Streams, small wetlands, and riparian forests are regarded as some of the park's most important natural resources. Much of the park today is maintained to replicate the Civil War viewshed during the Battle of Monocacy Junction, named for the Monocacy River which flows through the park. To represent the historic viewshed, the landscape of the park is mostly agricultural in nature.

The park is located within the Lower Monocacy River watershed (USGS hydrologic unit 02070009). The Monocacy River flows directly through and along the boundary of the national battlefield for approximately 2.5 miles. The landscape of MONO consists of the broad Monocacy River valley and ridges of less resistant geology. The river is confined to the west side of the Frederick Valley and tends to flow along the west base of the resistant ridges. These ridges, like Brooks Hill, are underlain by plunging anticlines of hard rock. Uplift and erosion has produced "valley and ridge" topography, with linear ridges and intervening valleys. To the west of the national battlefield, the landscape is a broad, open valley underlain by carbonate rocks that are susceptible to chemical erosion producing the local karst features (i.e., sinkholes and springs). To the east, the landscape is an elevated plateau underlain by fine-grained metamorphic rocks. Most of the battlefield is on the flat land which consists of terrace deposits overlying rocks of the Frederick Formation, just north of Interstate Highway 270 (Southwood and Denenny, 2006).

Within MONO, the I&M Water Quality and Quantity program monitors three sites, along Bush Creek, Harding's Run, and an unnamed perennial stream near the Gambrill Mill. The site on Bush Creek is approximately 300 meters upstream of the confluence with the Monocacy River. Bush Creek is the largest Monocacy River tributary within the national battlefield, a moderately narrow, rapidly flowing creek with scoured sections of banks and cobble beds from periodic high flows. The dominant land use within the Bush Creek watershed is agricultural. The site along the unnamed Gambrill Mill stream (herein called Visitor Center Creek) is located about 150 meters upstream of its confluence with the Monocacy River. The perennial stream receives water from the Thomas Farm Creek; however, it is primarily feed by the Visitor Center Pond and Gambrill Spring. There is heavy agricultural land use within this smaller watershed. The site along Harding's Run is located near the Worthington Farm, just upstream of where the Brooks Hill Loop Trail crosses the stream. Land use for the watershed is primarily agricultural

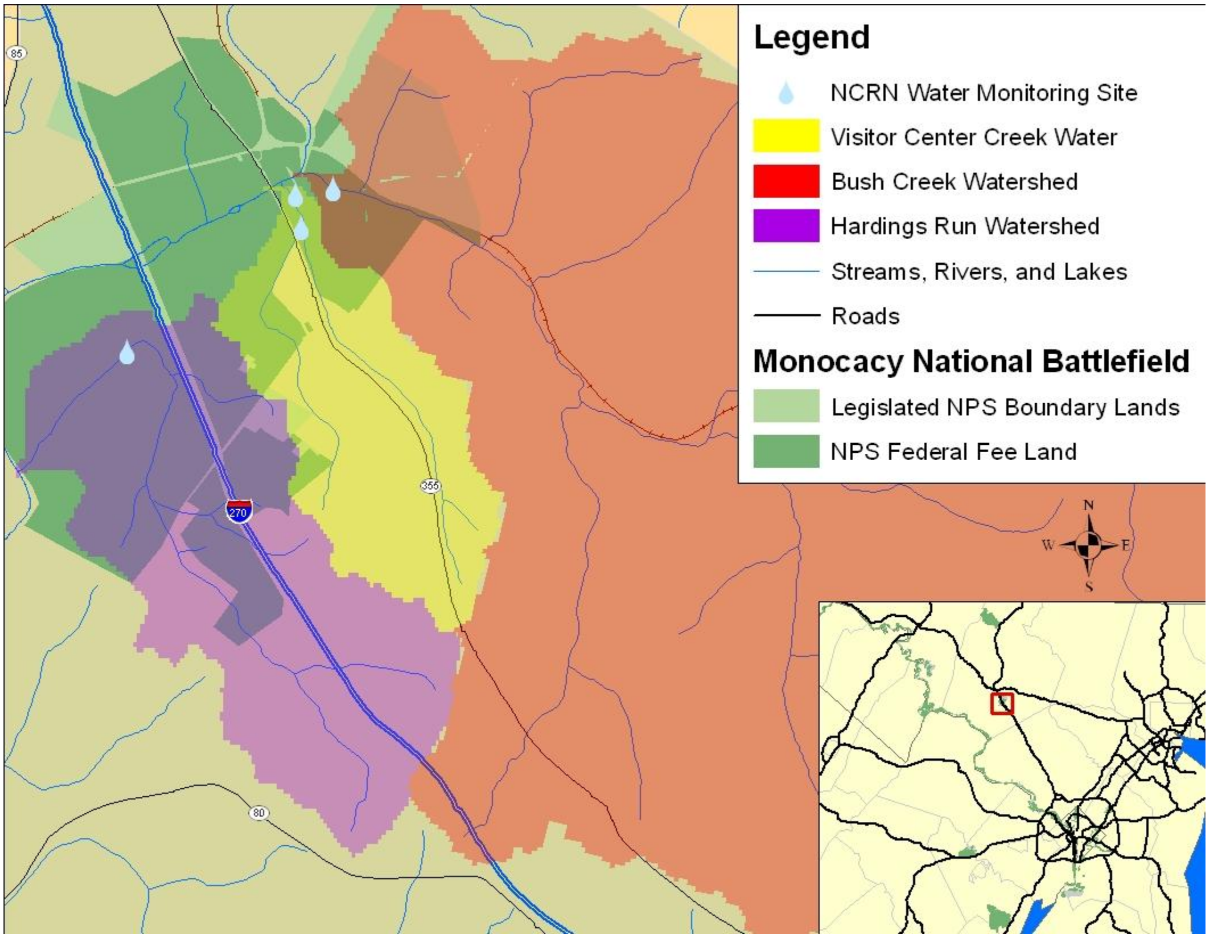

Figure 9: Relationship of the MONO stream monitoring sites to their watersheds and the park boundary

Table 8: Date range, number of site visits, and data range for the information covered in this report.

Characteristic	Units	Period of Record	Count	Min.	Max.
Bush Creek					
ANC	µeq/L	6/20/2005 - 9/13/2006	14	856	1520
DO (mg/L)	mg/l	5/23/2005 - 9/13/2006	15	3.6	13.1
Nitrate	mg/l	5/23/2005 - 9/13/2006	16	1.7	3.3
Nitrogen, Ammonia	mg/l	5/23/2005 - 9/13/2006	16	0.02	0.13
pH	None	5/23/2005 - 9/13/2006	15	7.48	9.42
Phosphorus	mg/l	5/23/2005 - 9/13/2006	16	0.04	1.48
Specific conductance	µS/cm	5/23/2005 - 9/13/2006	15	188	369
Harding's Run					
ANC	µeq/L	6/20/2005 - 8/15/2006	11	616	1656
DO (mg/L)	mg/l	5/23/2005 - 8/15/2006	12	0.16	11.6
Nitrate	mg/l	5/23/2005 - 8/15/2006	13	0.2	9.4
Nitrogen, Ammonia	mg/l	5/23/2005 - 8/15/2006	13	0.02	0.18

pH	None	5/23/2005 - 8/15/2006	12	6.82	7.68
Phosphorus	mg/l	5/23/2005 - 8/15/2006	13	0.19	2.19
Specific conductance	µS/cm	5/23/2005 - 8/15/2006	12	242	450
Visitor's Center Creek					
ANC	µeq/L	6/20/2005 - 9/13/2006	12	1152	3500
DO (mg/L)	mg/l	5/23/2005 - 9/13/2006	13	2.57	12.3
Nitrate	mg/l	5/23/2005 - 9/13/2006	14	1.5	14.2
Nitrogen, Ammonia	mg/l	5/23/2005 - 9/13/2006	14	-0	0.15
pH	None	5/23/2005 - 9/13/2006	13	7.14	8.39
Phosphorus	mg/l	5/23/2005 - 9/13/2006	14	0.12	2.48
Specific conductance	µS/cm	5/23/2005 - 9/13/2006	13	266	634

Table 9: Condition assessment and significance for site visits to Monocacy Streams 2005 – 2006.

Stream	ANC	DO	NH_3	NO_3	pH	PO_4	SC
Bush Creek	0	14	0	93	36	92	0
Harding's Run	0	50	0	62	0	100	17
Visitor's Center Creek	0	15	0	93	0	100	62

pH in Bush Creek exceeded the 8.5 threshold for aquatic life 5 out of 15 times. There is no discernible pattern to this but it might be linked to precipitation and runoff. It is also unclear how much of the watershed is on septic or sanitary sewer, which would also influence nutrients and specific conductance. Hilderbrand et al (2005) speculated the high pH recorded at some water quality sampling sites may be in response to agricultural lime applications in the area. This increase in dissolved ions also increases the specific conductance (White 1988).

Specific conductance is lower in Monocacy streams than it is in HAFE or ANTI. This may be due to differences in the chemistry and physical extent of the two areas of karst terrain.
The threshold exceedances for Hardings Run and Visitor's Center Creek may be due to adjacent pollution sources (feedlot and retention pond for Harding's Run and former Visitor's Center septic field for Visitor's Center Creek). Specific Conductance should be closely monitored and sources determined.

The lowest dissolved oxygen measurements for Bush Creek and Visitor's Center Creek occurred in spring 2006 before full leaf out when the streams still received full sunlight. Notice in figure 12, initially there are increases in dissolved oxygen, presumably from algae production. Observation of algae percent cover will be included in the 2007 report. Harding's Run low DO may be due to low flow issues. Hydrology data will also be presented in the 2007 report. The park has collected its own water quality data at additional stream and spring sites. All of the available data will be analyzed and presented for the 2007 report on Water Chemistry and Quantity.

These measures constitute a snap shot of stream conditions in time and space, and are not representative of quality over a 24 hour period. All of these measures are influenced to a certain degree by biological activity which follows diurnal and seasonal patterns of temperature and sunlight. There is not yet enough data to identify seasonal patterns or trends.

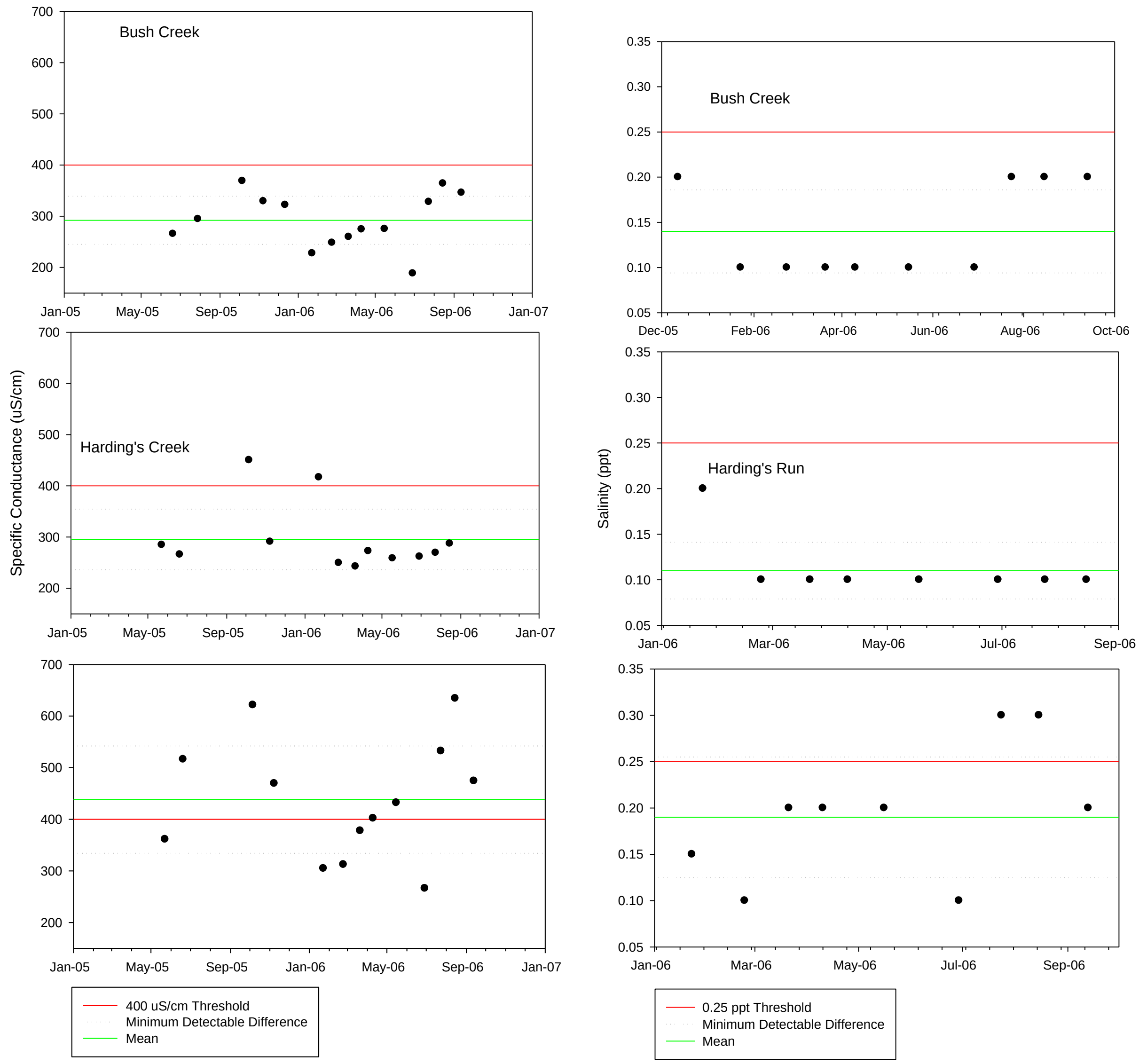

Figure 10: Specific Conductance and Salinity for Bush Creek, Hardings Run, and Visitor's Center Creek 2005 - 2006

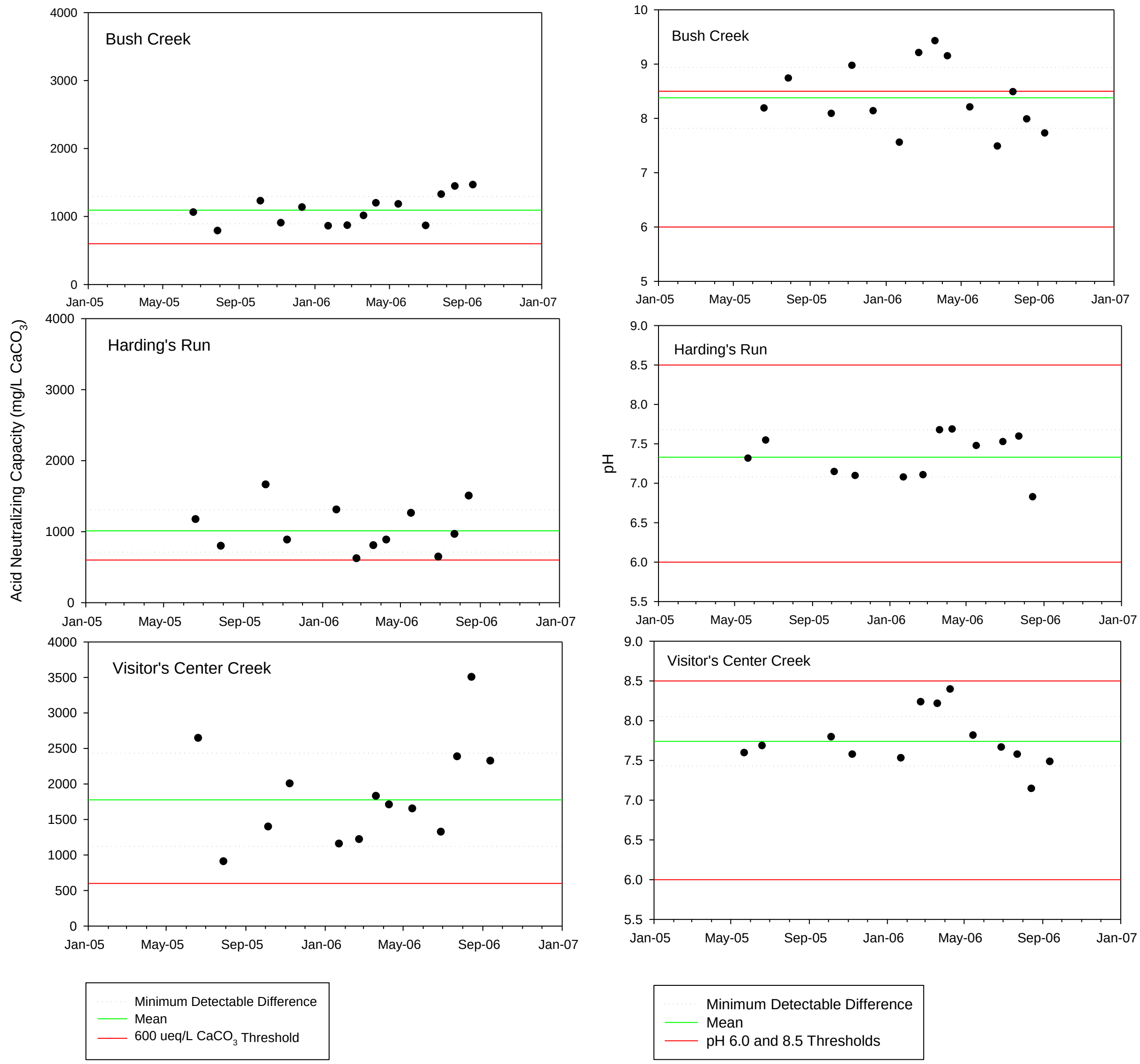

Figure 11: ANC and pH for Bush Creek, Hardings Run, and Visitor's Center Creek 2005 - 2006

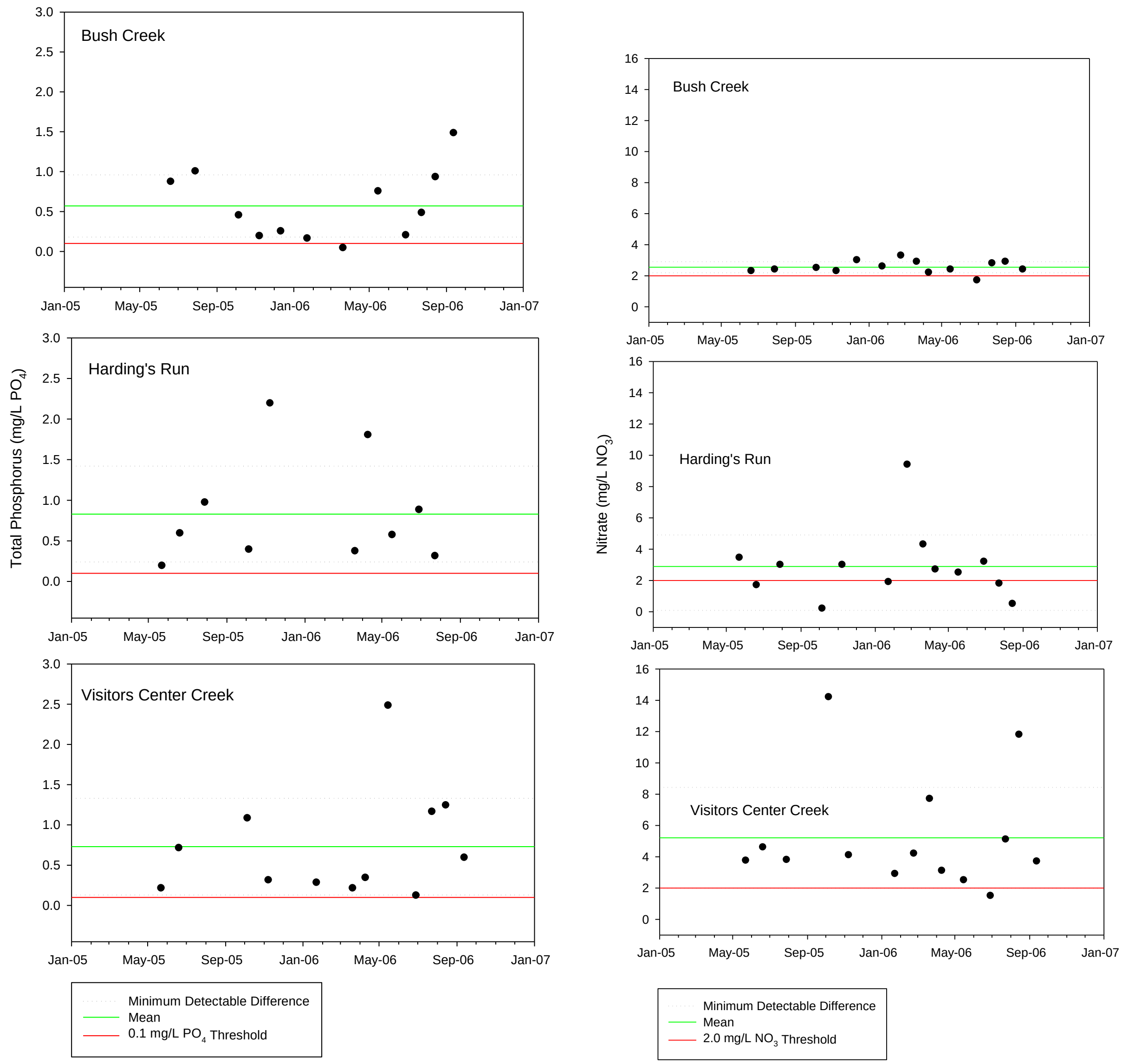

Figure 12: Phosphorus and Nitrate in Bush Creek, Hardings Run, and Visitor's Center Creek 2005 - 2006

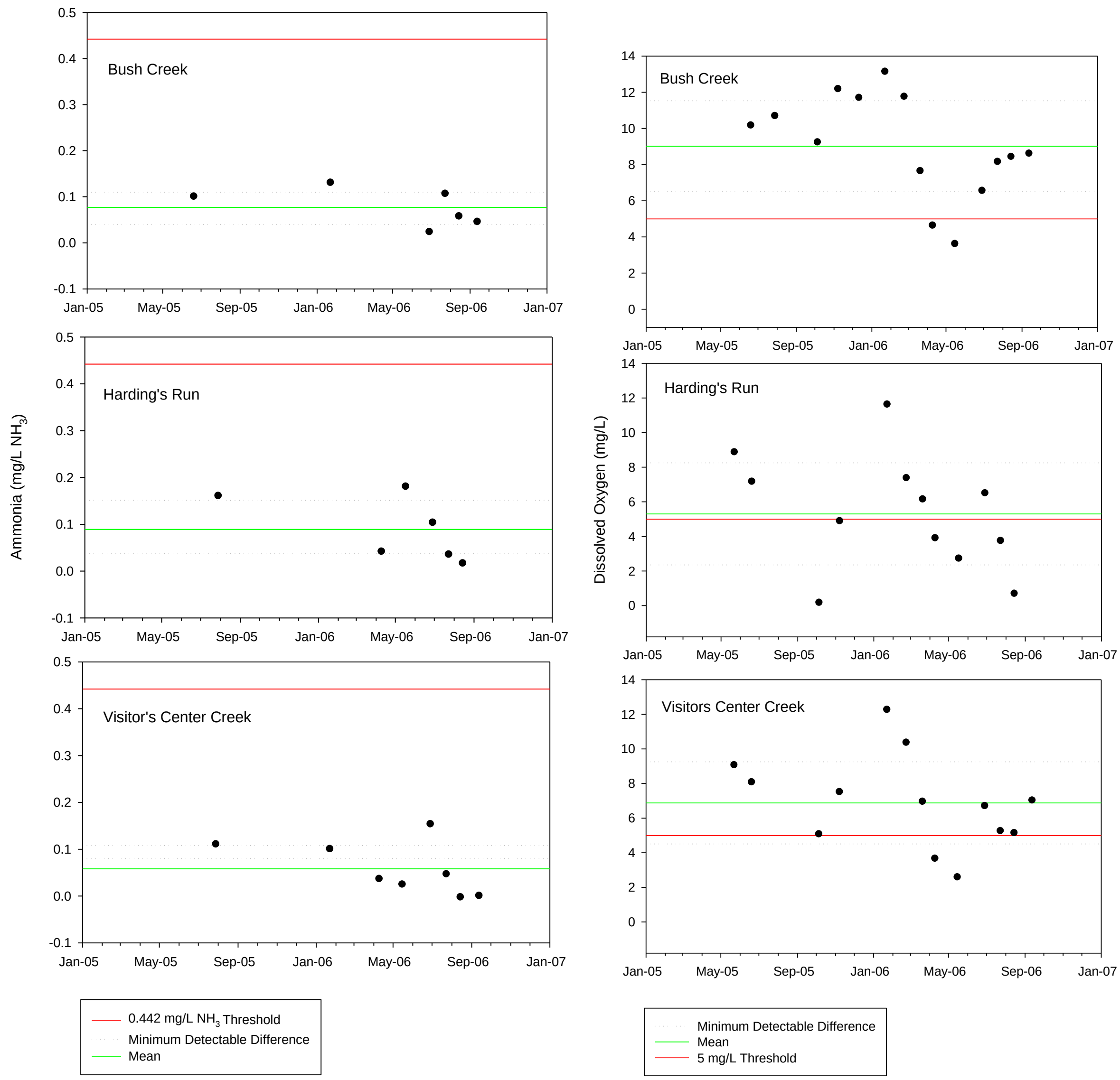

Figure 13: Ammonia and Dissolved Oxygen in Bush Creek, Hardings Run, and Visitor's Center Creek 2005 - 2006

Catoctin Mountain Park (CATO)

CATO encompasses 5,810 acres of secondary growth forest located in the mountains of the Catoctin Ridge in the north-central portion of Maryland. The park is located near Thurmont in Frederick County, Maryland in the Blue Ridge Physiographic Province.

CATO is part of the Lower Monocacy River watershed (USGS hydrologic unit 02070009). The park area is separated from the main ridge by two streams: Big Hunting Creek to the south and Owens Creek to the west, north, and east. Big Hunting Creek is 41.8 square miles in drainage, 15 miles long with a discharge of 3 to 5 cfs (2,238 gallons) per second. It is a tributary of the Monocacy River and forms the boundary between the National and State Parks. Big Hunting Creek flows in and out of the CATO boundary for roughly 4 miles. The headwaters of Big Hunting Creek are outside of the park, putting this creek at risk for potential problems that cannot be completely controlled by the park (Means 1995). Before entering the park, Big Hunting Creek runs off farms and lots and along MD Rte 77. The national park contains 7% of the creek's drainage basin. Developed areas in the park (Greentop, Round Meadow, Misty Mount, Maintenance Yard, Visitors Center, Administration Office, Park Central Road, Route 77, and Camp 3) contribute runoff to the creek. Water quality in the creek is very good, with bank erosion and flow rate the most significant problems. These problems have been further affected by construction of Cunningham Falls State Park dam. Big Hunting Creek is stocked by the state with hatchery-reared rainbow trout and brook trout. Brown trout naturally reproduce in this stream. Big Hunting Creek is open year-round for fishing and is managed as a fly-fishing-only, catch-and-release, no-kill area (Means 1995). Tributaries of Big Hunting Creek include Still Creek, Whiskey Still Creek (completely contained within CATO), Hauver Branch (within the state park) and Bear Branch (within the state park).

Owens Creek has a 39.8 square mile drainage and is managed for native brook and for naturally producing brown trout (Means 1995). The headwaters of Owens Creek begin inside the park . As the creek leaves through the park's north boundary it passes through and agricultural area and flows back into the park. The park contains 14.5% of Owens Creek's watershed, but fewer areas of the park contribute runoff to the creek (Round Meadow, Naval Housing Facilities, Owens Creek picnic area, Chestnut picnic area, Camp 3, and Owens Creek campground). A new wastewater treatment plant was located at the head of Owens Creek in the late 1990s. The plant discharges directly into the stream and wetland where Owens Creek originates.

Within CATO, the I&M Water Quality and Quantity program monitors three sites: Big Hunting Creek just downstream of the Route 77 crossing, near the park's administrative offices; Whiskey Still Creek near the park's Visitor Center, between the Route 77 crossing and Big Hunting Creek; Owens Creek at the entrance for the Campground.

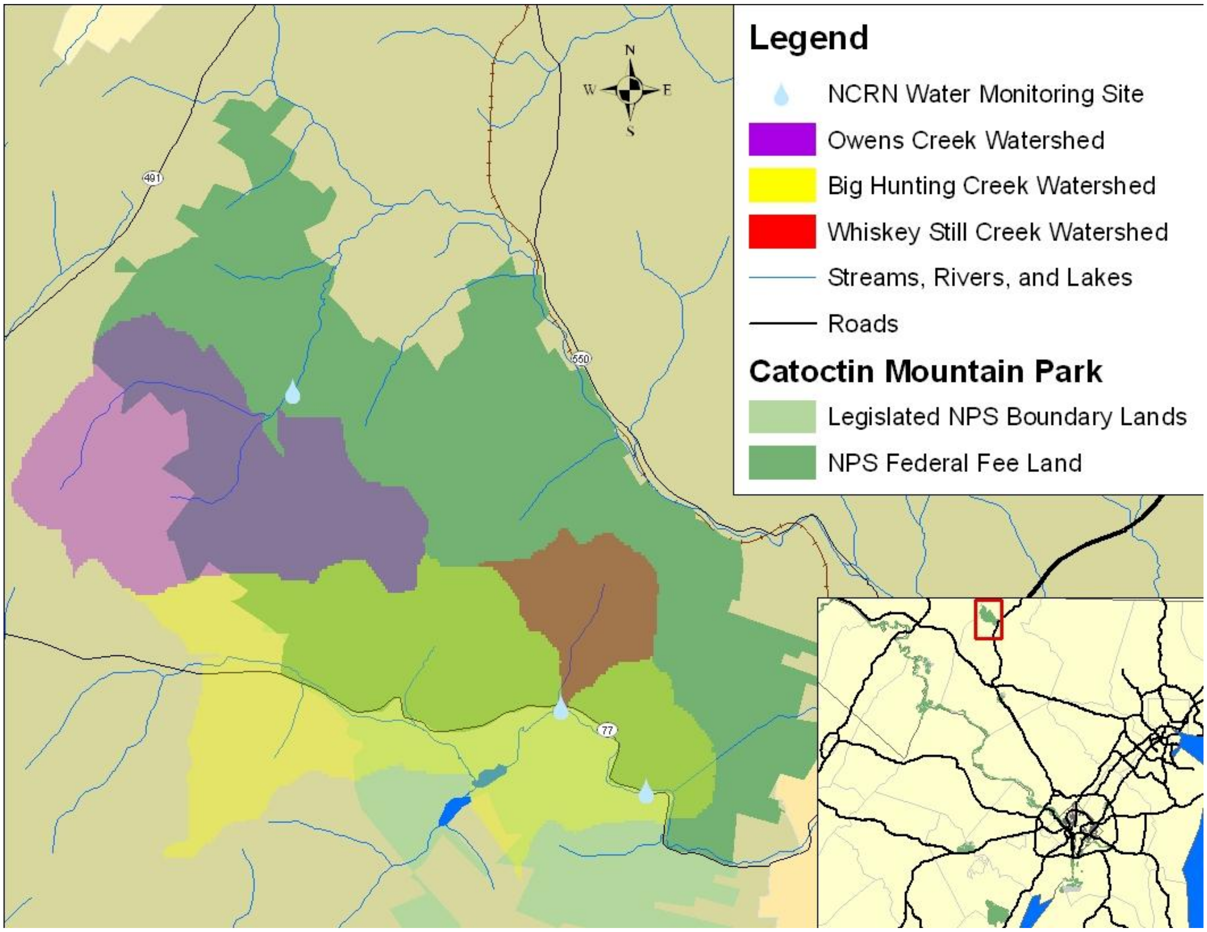

Figure 14: Relationship of CATO stream monitoring sites to their watersheds and the park boundary

Table 10: Date range, number of site visits, and data range for the information covered in this report

Characteristic	Units	Period of Record	Count	Min.	Max.
Big Hunting Creek					
ANC	µeq/L	6/20/2005 - 9/13/2006	13	280	802
DO (mg/L)	mg/l	6/20/2005 - 9/13/2006	13	2.69	12.4
Nitrate	mg/l	6/20/2005 - 9/13/2006	13	0.4	1.1
Nitrogen, Ammonia	mg/l	6/20/2005 - 9/13/2006	13	0	0.12
pH	None	6/20/2005 - 9/13/2006	13	6.71	7.76
Phosphorus	mg/l	6/20/2005 - 9/13/2006	13	0.09	1.79
Specific conductance	µS/cm	6/20/2005 - 9/13/2006	13	86	1313
Owens Creek					
ANC	µeq/L	6/20/2005 - 9/13/2006	13	336	840
DO (mg/L)	mg/l	6/20/2005 - 9/13/2006	13	2.94	11.8
Nitrate	mg/l	6/20/2005 - 9/13/2006	13	0.1	1.3
Nitrogen, Ammonia	mg/l	6/20/2005 - 9/13/2006	13	-0	0.11
pH	None	6/20/2005 - 9/13/2006	13	6.83	7.73
Phosphorus	mg/l	6/20/2005 - 9/13/2006	13	0.18	4.42
Specific conductance	µS/cm	6/20/2005 - 9/13/2006	13	103	171
Whiskey Still Creek					
ANC	µeq/L	6/20/2005 - 9/12/2006	13	378	880
DO (mg/L)	mg/l	6/20/2005 - 9/12/2006	13	3.46	11.8
Nitrate	mg/l	6/20/2005 - 9/12/2006	13	0.1	0.6
Nitrogen, Ammonia	mg/l	6/20/2005 - 9/12/2006	13	0	0.05
pH	None	6/20/2005 - 9/12/2006	13	6.84	7.93
Phosphorus	mg/l	6/20/2005 - 9/12/2006	13	0.2	1.11
Specific conductance	µS/cm	6/20/2005 - 9/12/2006	13	73.8	148

Table 11: Condition assessment and significance for site visits to Catoctin Streams 2005 – 2006.

Stream	ANC	DO	NH_3	NO_3	pH	PO_4	SC
Big Hunting Creek	0	15	0	0	0	80	8
Owens Creek	0	15	0	0	0	100	0
Whiskey Still Creek	0	15	0	0	0	100	0

The one parameter for which CATO streams significantly and consistently fail to meet threshold is phosphorus. Owens Creek and Big Hunting Creek are probably receiving inputs from off-property fertilizing. Owens Creek receives water from a sewage treatment plant inside the park. Whiskey Still Creek should not have an elevated phosphorus level based on current knowledge of its drainage, since there are no known un-natural sources of phosphorus for it. Perhaps the threshold requires reconsideration. Potential sources of phosphorus within the watersheds should be investigated.

Specific conductivity is only a problem for Big Hunting Creek. The mean does not exceed the threshold and observations are comparable to those at Owens Creek and Whiskey Still Creek, within the comfort zone of most organisms and in a low range expected of waters flowing over insoluble bedrock. However, the mean and its significance are thrown off by an outlier of 1313 µS/cm in December 2005 (see figure 15). Big Hunting Creek runs through a state park and passes under Route 77 just before our sampling location. The other two streams are within the park boundary for a longer distance before we sample them. Supposedly de-icing compounds are not used in the area, and are definitely not used in the National Park unit, but this is something to watch in the winter.

All three streams in CATO experienced low DO in late spring / early summer2006 (see figure 18). This followed a peak in DO during the early spring which may have been the result of an algal bloom during leaf-off. As the algae decomposed after the bloom, DO was consumed. Observations of algal coverage will be presented with the 2007 data.

These measures constitute a snap shot of stream conditions in time and space, and are not representative of quality over a 24 hour period. All of these measures are influenced to a certain degree by biological activity which follows diurnal and seasonal patterns of temperature and sunlight. There is not yet enough data to identify seasonal patterns or trends. In 1978, Catoctin began a long-term water quality-monitoring program analyzing monthly samples from eight sites within the park for temperature, dissolved oxygen, pH, ammonia, salinity, specific conductivity, turbidity, and alkalinity. This data will be analyzed and presented in the 2007 report.

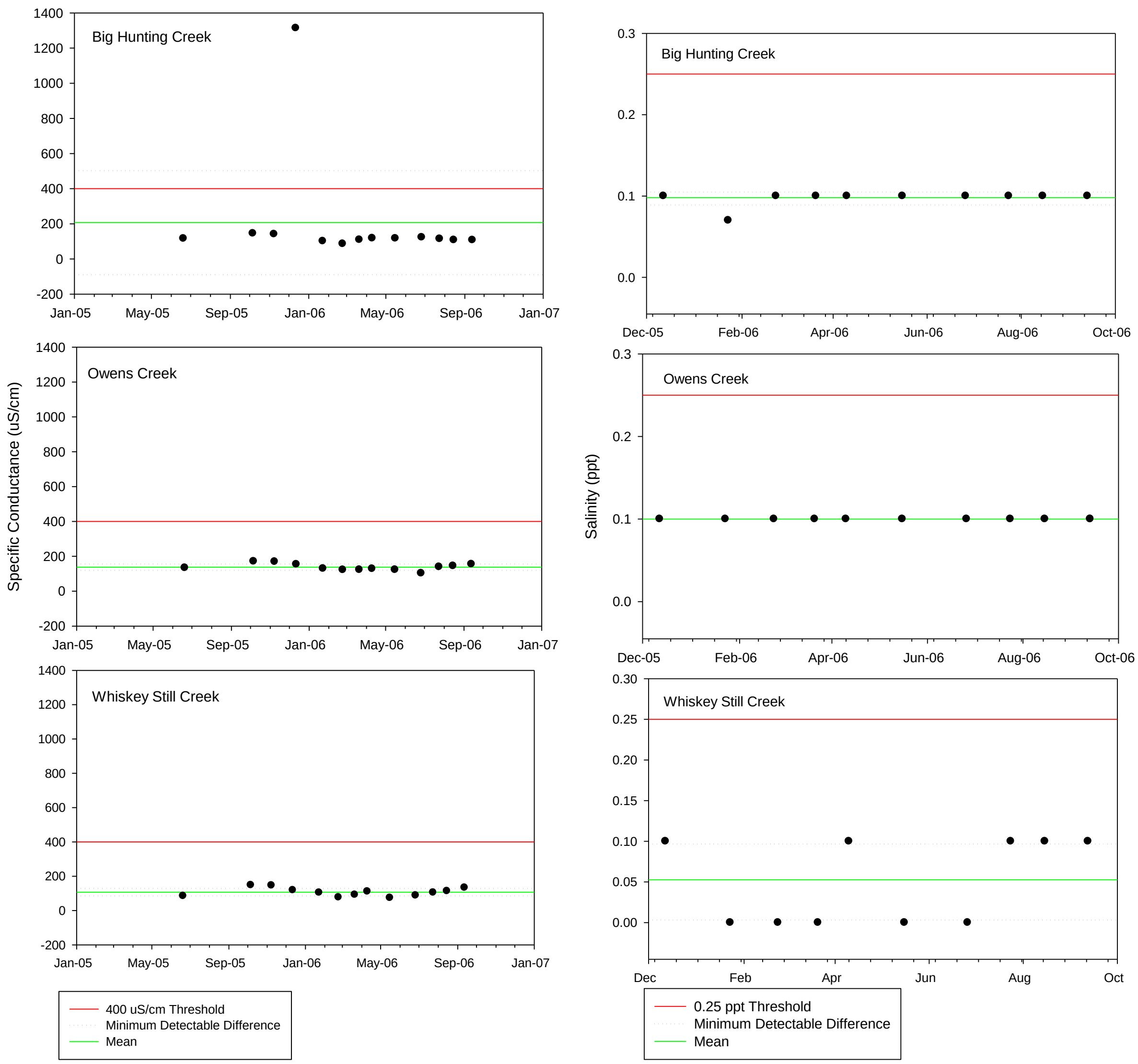

Figure 15: Specific Conductance and Salinity of Big Hunting Creek, Owens Creek, and Whiskey Still Creek 2005-2006

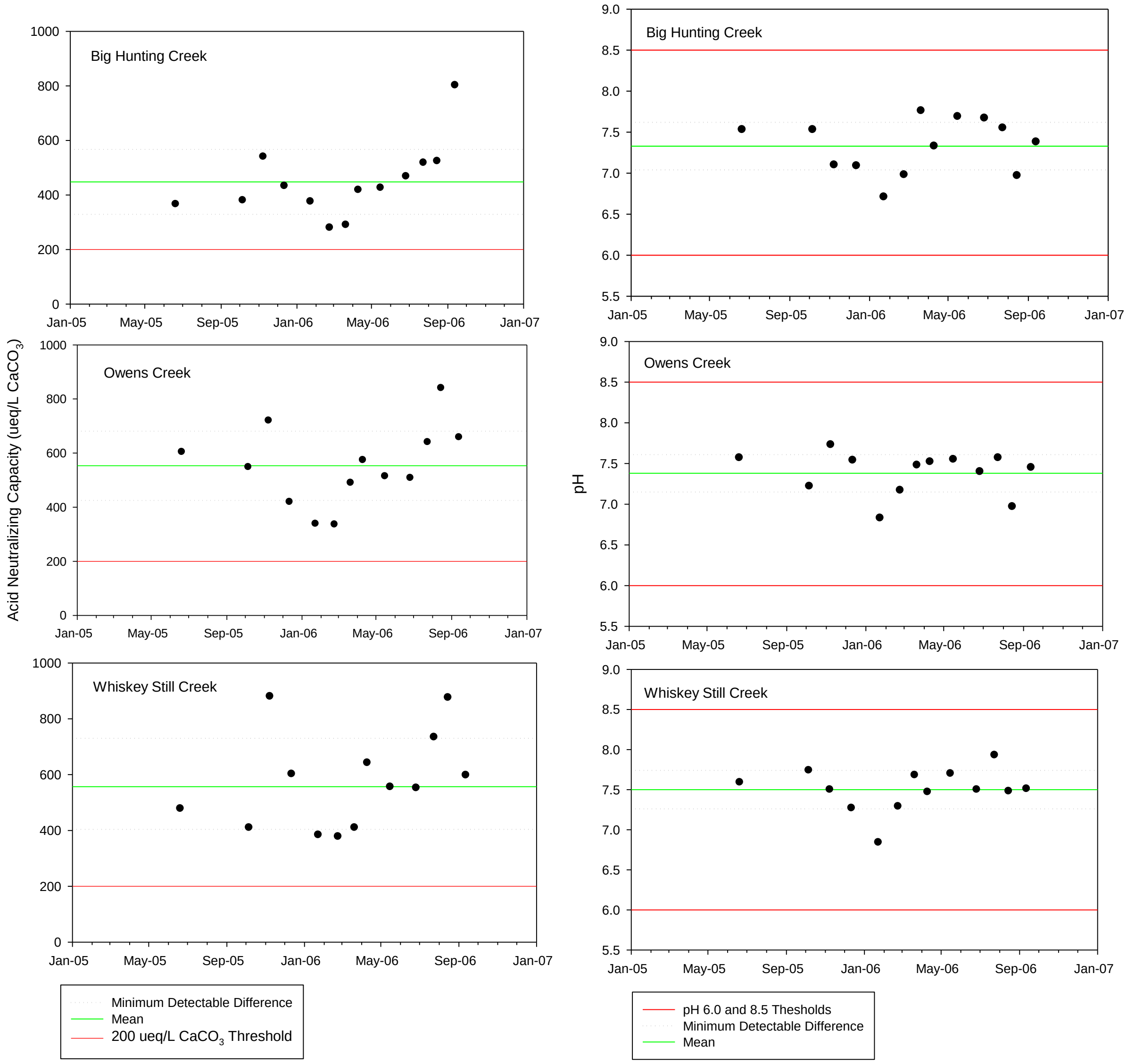

Figure 16: Acid Neutralizing Capacity and pH of Big Hunting Creek, Owens Creek, and Whiskey Still Creek 2005-2006

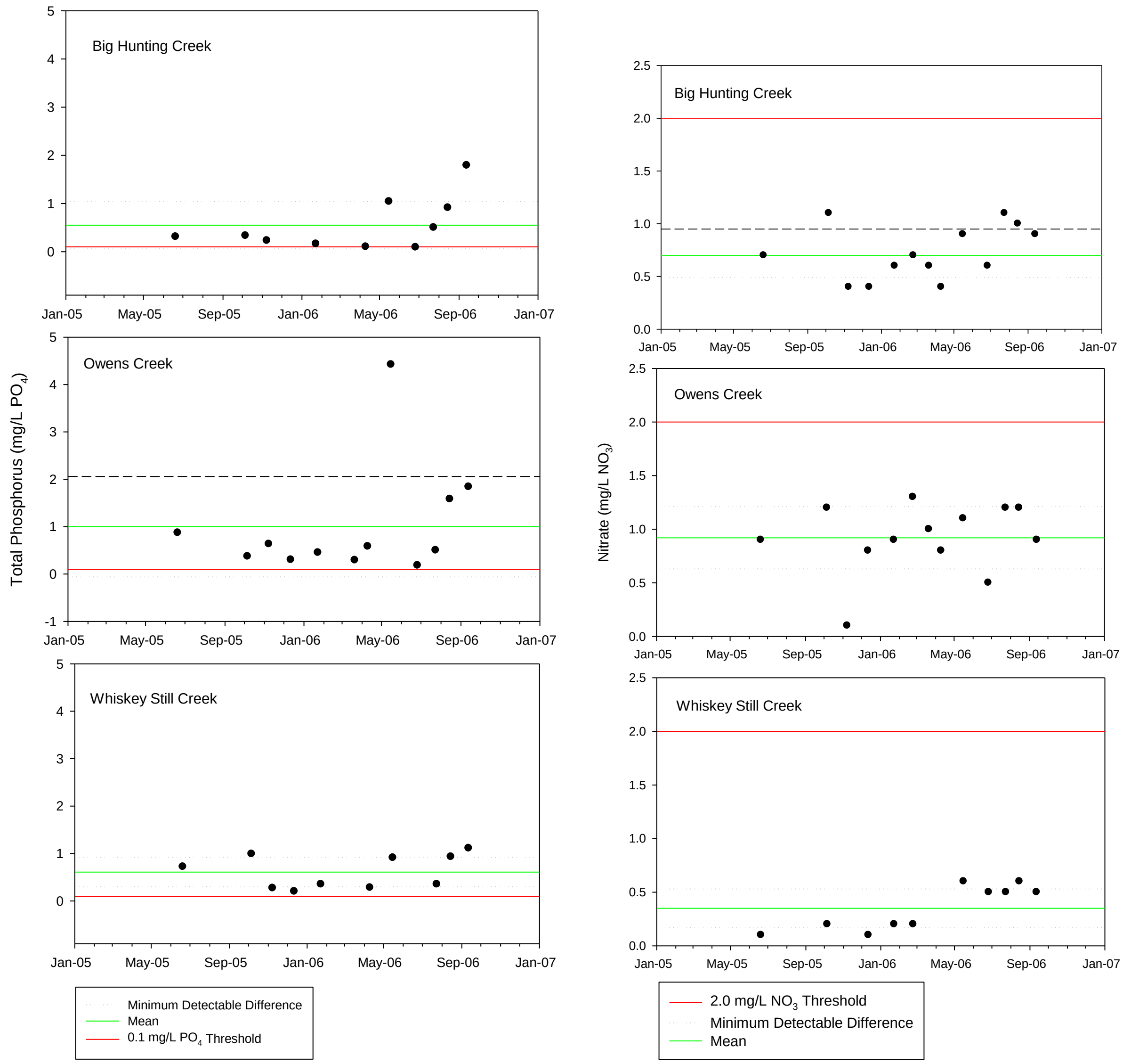

Figure 17: Phosphorus and Nitrate in Big Hunting Creek, Owens Creek, and Whiskey Still Creek 2005-2006

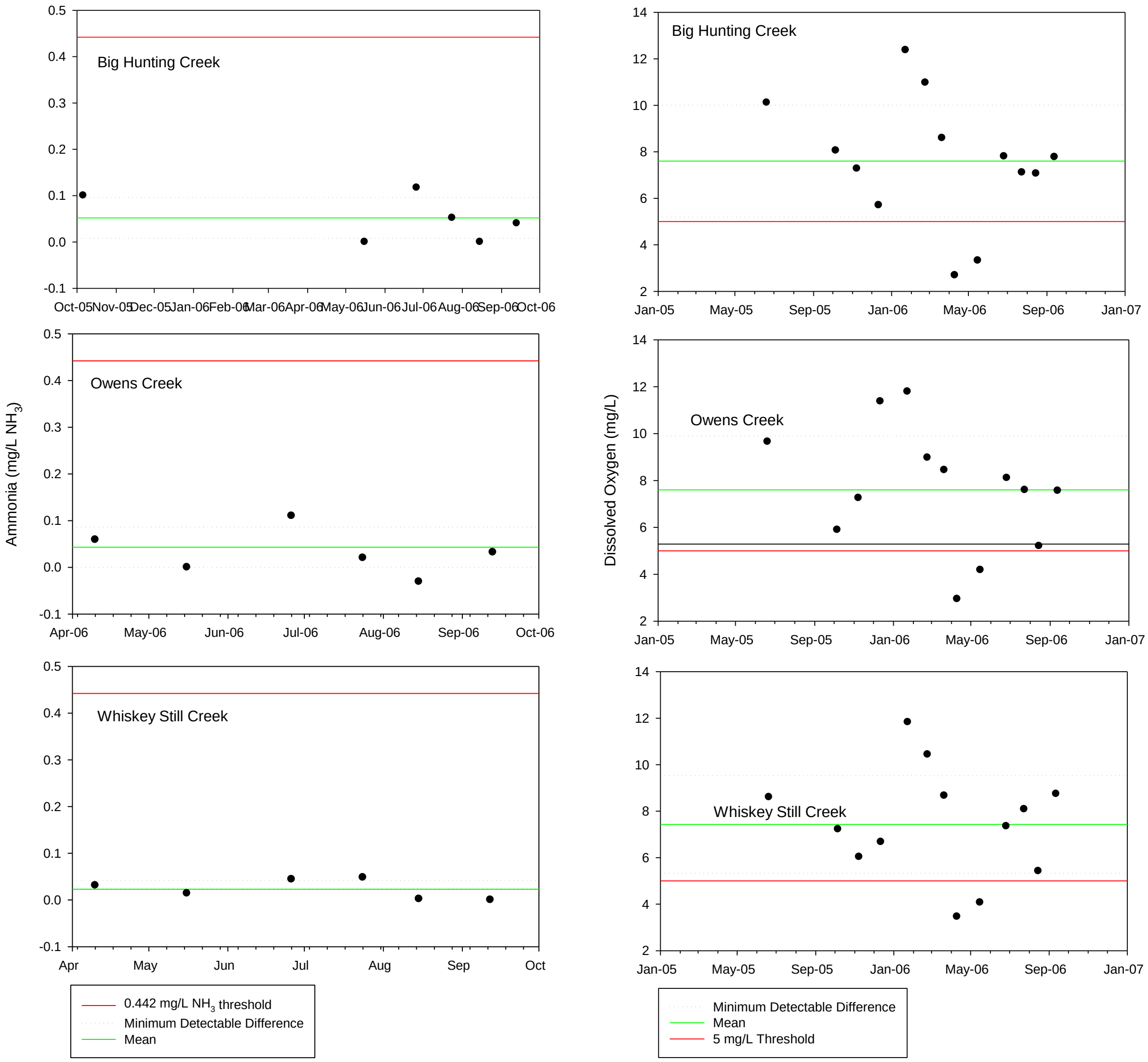

Figure 18: Ammonia and Dissolved Oxygen in Big Hunting Creek, Owens Creek, and Whiskey Still Creek 2005-2006

Manassas National Battlefield Park (MANA)

MANA was established in 1940 to preserve the scene of two major Civil War battles that took place a few miles north of the prized railroad junction of Manassas, Virginia, in 1861 and 1862. The 5,073acre a park is located approximately 72 km southwest of Washington, D.C. in Manassas County, Virginia within the Piedmont physiographic region. MANA is characterized by gently rolling hills with a patchwork of open fields and forests with riparian vegetation along the streams. The park contains about 16 miles of named streams and several unnamed watercourses. Bull Run, a tributary to the Occoquan River, forms the parks eastern boundary. Several major commuter routes run through or immediately adjacent to MANA, including Routes 234 and 29 and Interstate 66. Development of the surrounding area is the likely source of most impacts to the park's water resources.

MANA is part of the Middle Potomac-Anacostia-Occoquan watershed (USGS hydrologic unit 02070010). The headwaters of Young's Branch and nearly all of its tributaries occur on parkland. Most of Dogan Branch watershed lies on parkland; however, a good portion of the stream runs through private lands. Chinns Branch occurs entirely within MANA. Holkums Branch makes up another small watershed in the park, however, its headwater begin on the Manassas campus of Northern Virginia Community College. Both Young's Branch and Holkums Branch empty into Bull Run. Several smaller intermittent tributaries drain the remainder of the park.

NCRN monitors 4 streams in MANA: Young's Branch at the downstream crossing of the First Battle of Manassas Trail, approximately 600 meters upstream of it confluence with Bull Run; Dogan Branch between Route 29 and a privately held pond, near the New York Monuments; Chinns Branch just upstream of it confluence with Young's Branch, near the intersection of Routes 29 and 234; Holkum's Branch approximately 300 meters upstream of it confluence with Bull Run. Since this stream's headwaters occur off of parkland, it could serve as an interesting example of the impacts of surrounding land use. Chinns Branch and Dogan Branch are tributaries of Young's Branch. Young's Branch and Holkum's Branch are tributaries of Bull Run.

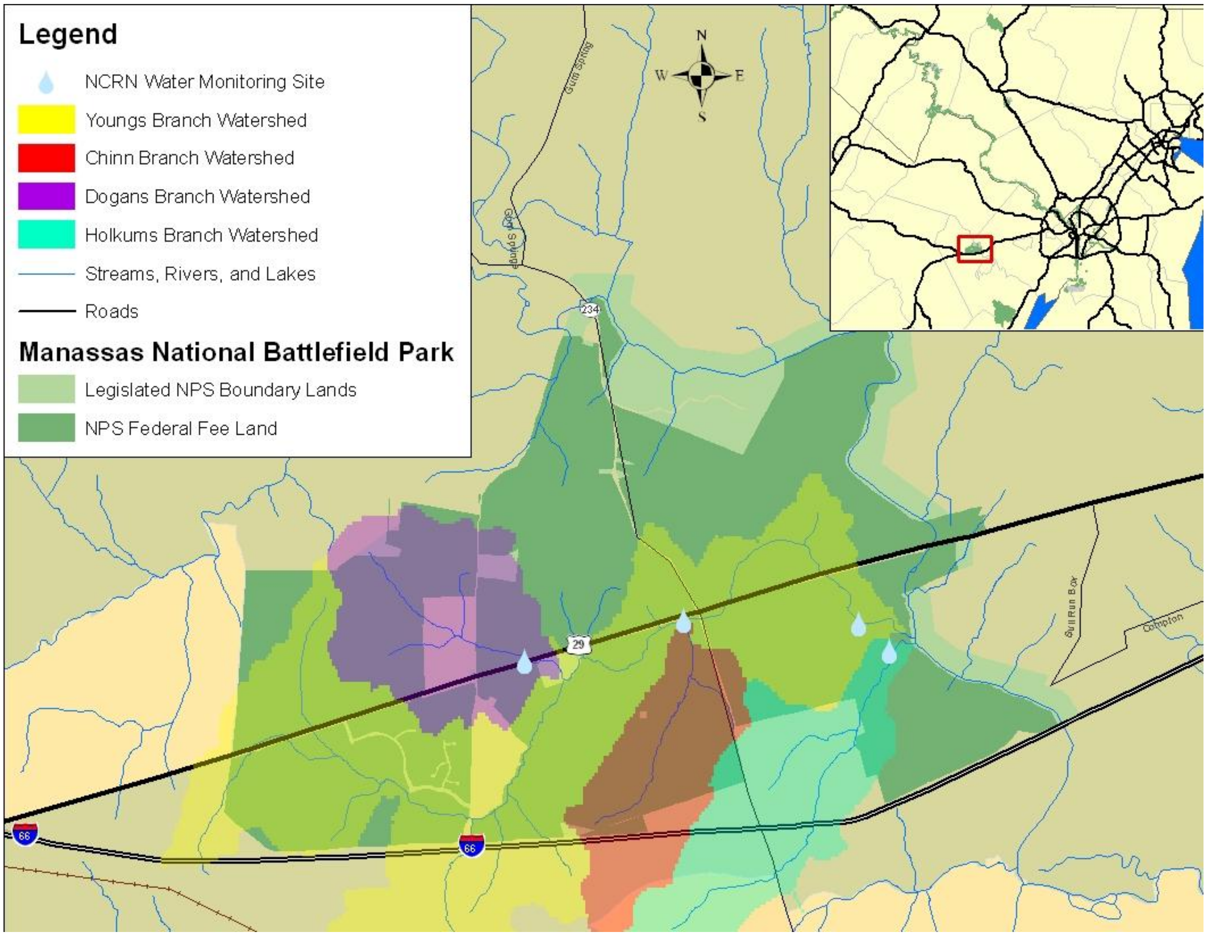

Figure 19: Relationship of MANA stream monitoring sites to their watersheds and the park boundary

Table 12: Date range, number of site visits, and data range for the information covered in this report.

Characteristic	Units	Period of Record	Count	Cens.	Incl.	Min.	Max.
Chinn's Branch							
ANC	µeq/L	6/22/2005 - 9/18/2006	13	0	13	648	3396
DO (mg/L)	mg/l	6/22/2005 - 9/18/2006	13	0	13	2.85	13.9
Nitrate	mg/l	6/22/2005 - 9/18/2006	13	6	7	0.06	0.6
Nitrogen, Ammonia	mg/l	6/22/2005 - 9/18/2006	13	6	7	0	0.7
pH	None	6/22/2005 - 9/18/2006	13	2	11	7	7.81
Phosphorus	mg/l	6/22/2005 - 9/18/2006	13	4	9	0.11	5.83
Specific conductance	µS/cm	6/22/2005 - 9/18/2006	13	0	13	195	577
Dogan Branch							
ANC	µeq/L	6/22/2005 - 8/11/2006	12	0	12	600	3752
DO (mg/L)	mg/l	6/22/2005 - 8/11/2006	12	0	12	2.92	10.9
Nitrate	mg/l	6/22/2005 - 8/11/2006	12	8	4	0.3	0.4
Nitrogen, Ammonia	mg/l	6/22/2005 - 8/11/2006	12	6	6	-0	0.09
pH	None	6/22/2005 - 8/11/2006	12	2	10	6.56	8.28
Phosphorus	mg/l	6/22/2005 - 8/11/2006	12	4	8	0.16	2.23
Specific conductance	µS/cm	6/22/2005 - 8/11/2006	12	0	12	164	443
Holkums Branch							
ANC	µeq/L	6/22/2005 - 9/18/2006	12	0	12	616	1536
DO (mg/L)	mg/l	6/22/2005 - 9/18/2006	12	0	12	0.98	15.3
Nitrate	mg/l	6/22/2005 - 9/18/2006	12	3	9	0.1	0.6
Nitrogen, Ammonia	mg/l	6/22/2005 - 9/18/2006	12	5	7	0	0.13
pH	None	6/22/2005 - 9/18/2006	13	2	11	0	7.89
Phosphorus	mg/l	6/22/2005 - 9/18/2006	12	7	5	0.29	2.26
Specific conductance	µS/cm	6/22/2005 - 9/18/2006	13	0	13	0	994
Young's Branch							
ANC	µeq/L	6/22/2005 - 9/18/2006	13	0	13	784	2520
DO (mg/L)	mg/l	6/22/2005 - 9/18/2006	13	0	13	2.78	12.8
Nitrate	mg/l	6/22/2005 - 9/18/2006	13	8	5	0.1	0.4
Nitrogen, Ammonia	mg/l	6/22/2005 - 9/18/2006	13	6	7	0.04	0.14
pH	None	6/22/2005 - 9/18/2006	13	1	12	6.83	7.99
Phosphorus	mg/l	6/22/2005 - 9/18/2006	12	5	7	0.18	1.46
Specific conductance	µS/cm	6/22/2005 - 9/18/2006	13	0	13	244	723

Table 13: Condition assessment and significance for site visits to Manassas Streams 2005 – 2006.

Stream	ANC	DO	NH_3	NO_3	pH	PO_4	SC
Chinn's Branch	0	31	14	0	0	100	38
Dogan Branch	0	33	0	0	0	100	25
Holkums Branch	0	45	0	0	0	100	42
Young's Branch	0	46	0	0	0	100	70

All streams sampled in MANA exceed the specific conductance threshold at some time. For Young's Branch and its tributaries, which run through agricultural fields, it tends to be during the summer months (see figure 20), which would coincide with the application of fertilizer. In Holkums Branch it tends to be during the late winter and early spring, which would coincide with the application of pavement de-icers on the NOVA campus. The statistical significance of specific conductance should be resolved with more observations in the future.

All streams sampled in MANA exceed the phosphorus threshold at some time. For Young's Branch and its tributaries, which run through agricultural fields, it tends to be during the summer months (see figure 20), which would coincide with the application of fertilizer. In Holkums Branch it tends to be during the late winter and early spring, which would coincide with the application of pavement de-icers on the NOVA campus. There are several instances when PO4 measured was below detectable limit. If these instances were considered PO4 exceedances for Holkums Branch and Young's Branch particularly are fewer than would seem at first glance. However there is no discernible pattern and the source is unknown. Possible PO4 sources in the watersheds should be investigated, including orthophosphate additions to tap water. Particularly since nitrate is not also a problem and DO does not seem to follow the same ups and downs as PO4 (see figure 23). Observations of algal abundance will be presented in the 2007 report.

There was a high NH3 value recorded July 2006 in Chinn's Branch (see figure 23). We are not sure why. Potential sources in the watershed require identification.

All 4 streams experienced low DO in summer 2006, following algal blooms. This is to be expected with the PO4 levels above threshold. There was also a drop in December 2005 for which we are unable to provide any explanation.

These measures constitute a snap shot of stream conditions in time and space, and are not representative of quality over a 24 hour period. All of these measures are influenced to a certain degree by biological activity which follows diurnal and seasonal patterns of temperature and sunlight. There is not yet enough data to identify seasonal patterns or trends.

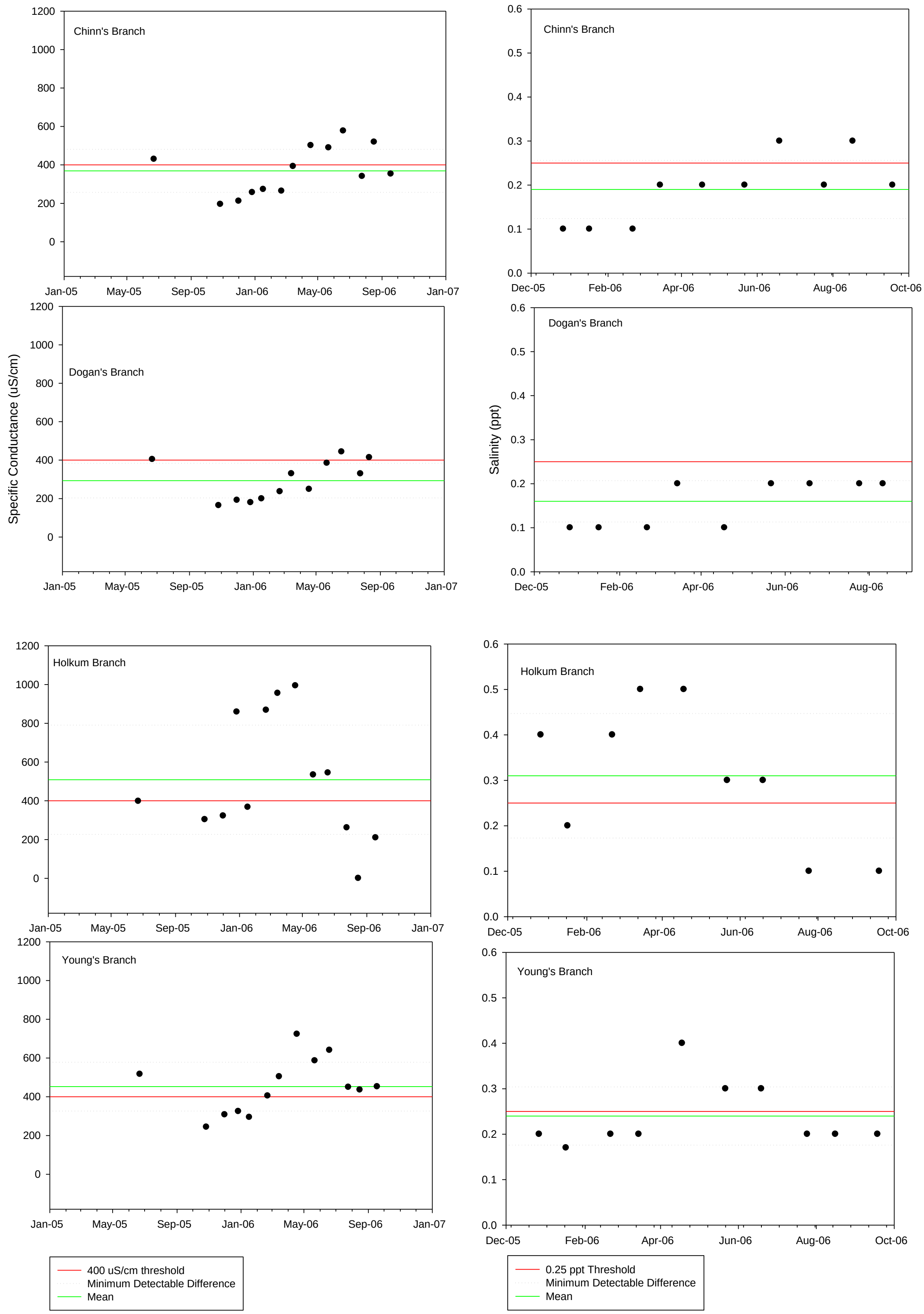

Figure 20: Specific Conductance and Salinity in Manassas NBP 2005-2006

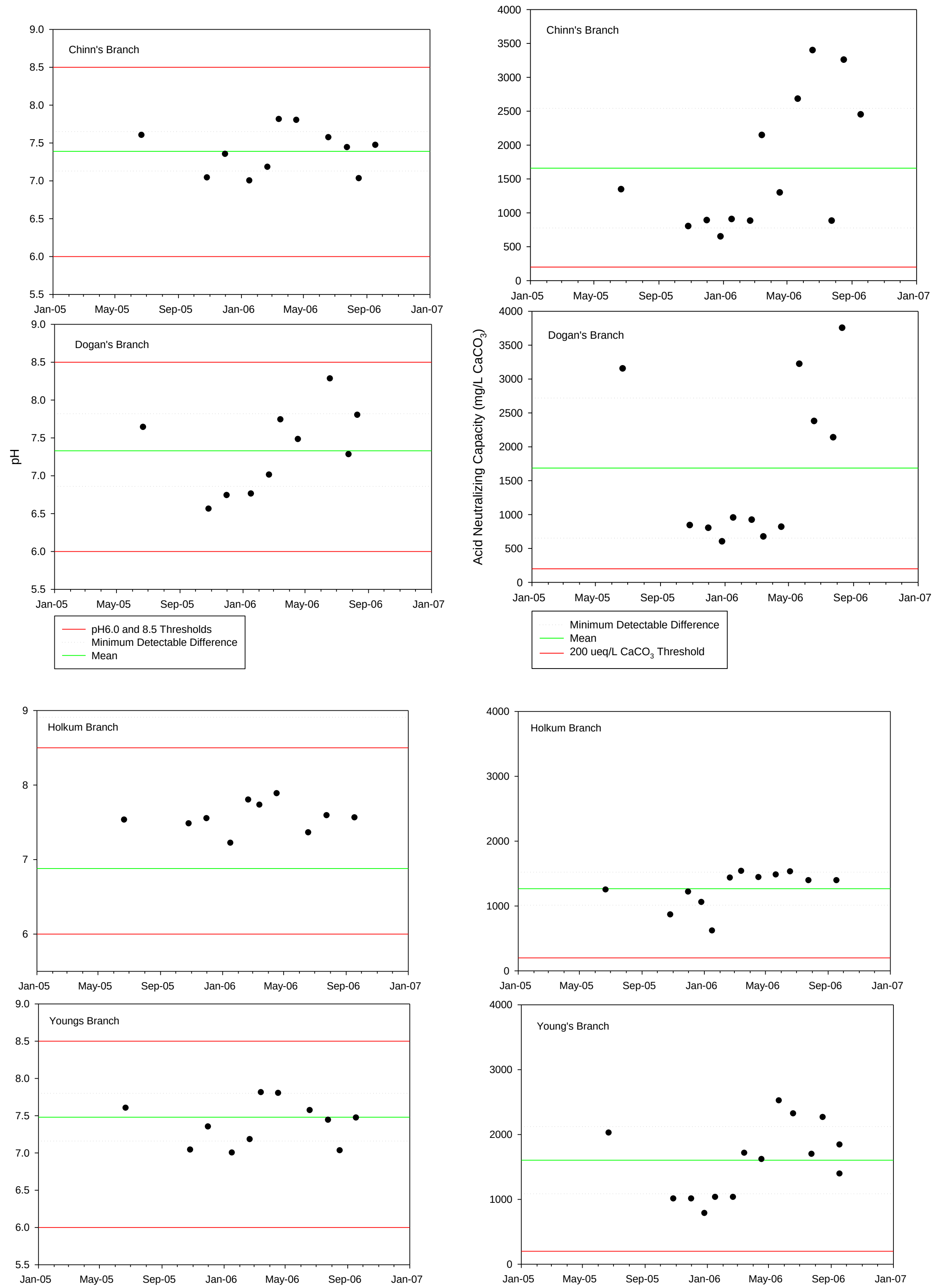

Figure 21: pH and Acid Neutralizing Capacity in Manassas NBP 2005-2006

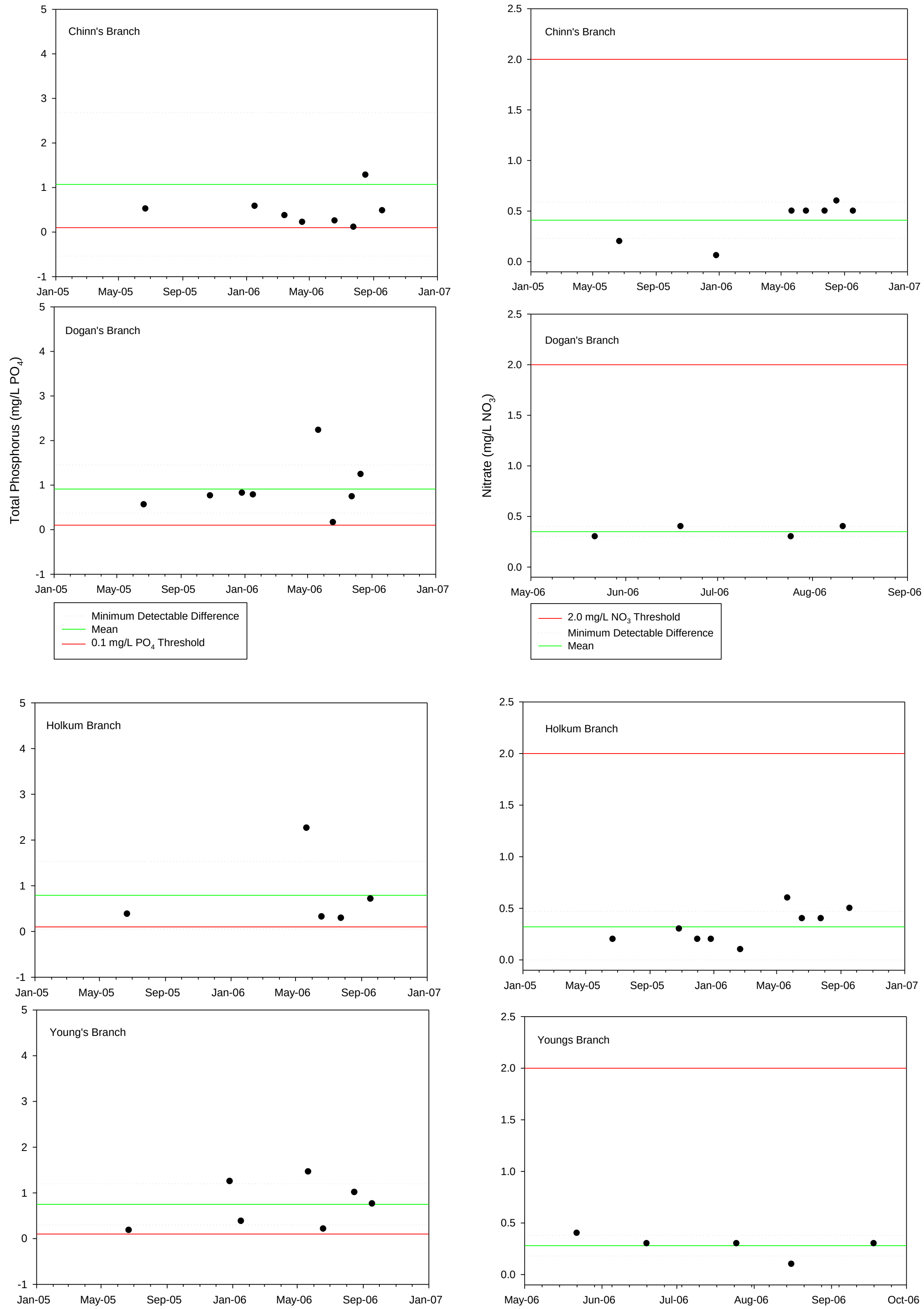

Figure 22: Total Phosphorus and Nitrate in Manassas NBP streams 2005-2006

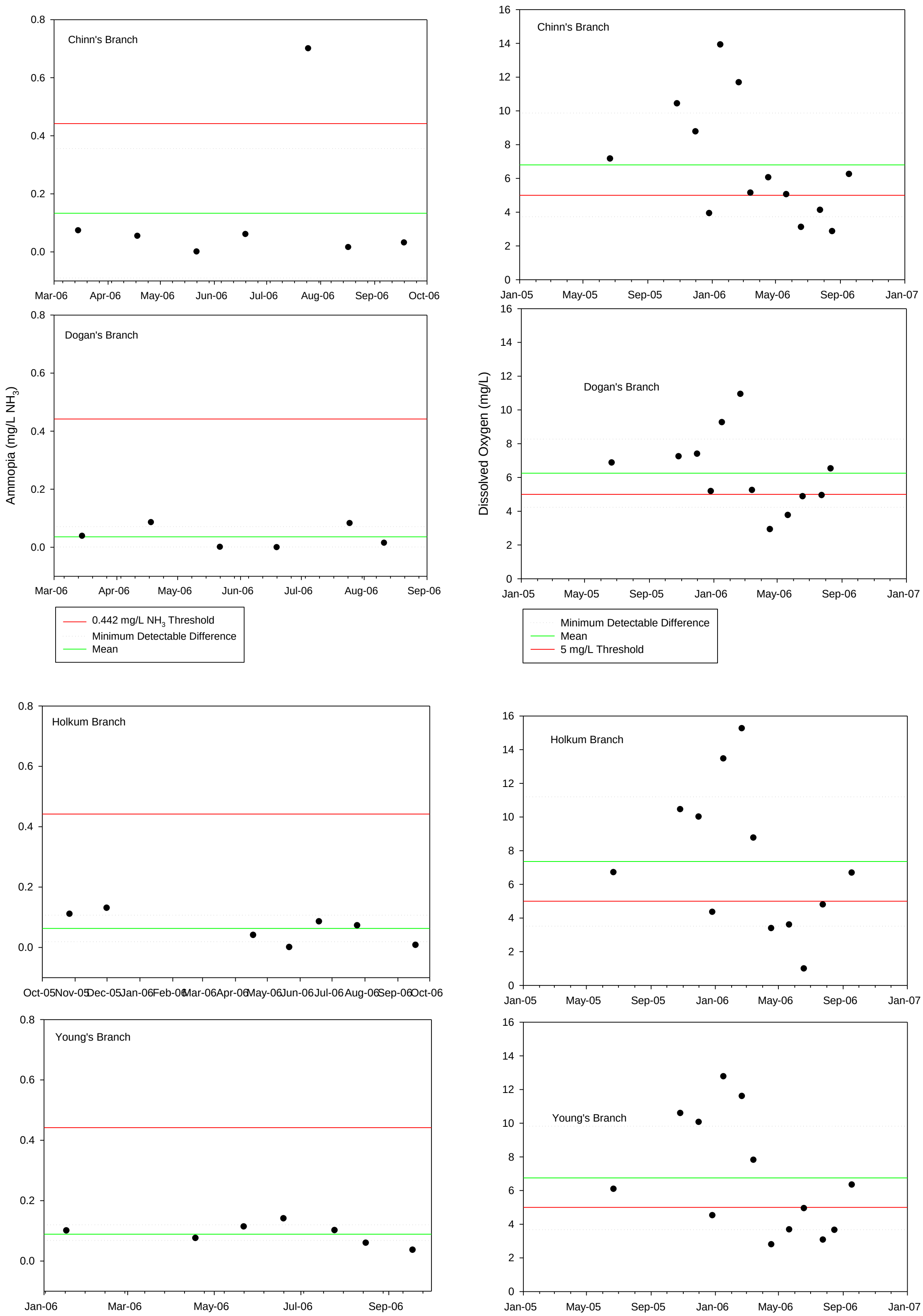

Figure 23: Ammonia and Dissolved Oxygen in Manassas NBP streams 2005-2006

Prince William Forest Park (PRWI)
PRWI is a 15,000-acre park located within the Piedmont and Coastal Plain Physiographic Provinces in Prince William and Stafford Counties, Virginia. Two stream systems run through PRWI, the Quantico Creek and the Chopawamsic Creek, and eventually empty into the Potomac River. Numerous intermittent and perennial tributaries exist wholly on park land and empty into these two systems. The Fall Line, marking the transition from Piedmont to Coastal Plane, crosses the park, creating small falls on South Fork Quantico Creek and some of its tributaries. Historically, land use within these two systems has been agricultural or industrial in nature. Today, both watersheds are primarily forested, but contain some military-related land use. Because the park includes two physiographic provinces (Piedmont and Coastal Plain) and lies in the transition zone between northern and southern climates, it exhibits a wide range of habitat and vegetative communities. It is now the only natural area in the National Park System that contains a significant expanse of piedmont forest.

The park is located within the Lower Potomac River drainage basin (USGS hydrologic unit 02070011). PRWI contains portions of two stream systems: Quantico Creek and Chopawamsic Creek. The 30 square mile Quantico Creek watershed is comprised of two streams, North Fork Quantico Creek and South Fork Quantico Creek, and numerous tributaries. The headwaters of Quantico Creek occur within PRWI and the stream runs through two former mining sites and two small man-made impoundments. The land use is primarily forested. Nine square miles of South Fork Quantico Creek headwaters lie within Quantico Marine Corps Base. The other four square miles are in private ownership. The remaining 17 square miles of the watershed are within PRWI. Protection of the Quantico Creek watershed is included in the park's enabling legislation.

The Chopawamsic Creek watershed includes the South, North, and Middle Branches of Chopawamsic Creek, and numerous tributaries. The headwaters for all three branches occur within the lands of Quantico Marine Corps Base. Only portions of North Branch and Middle Branch Chopawamsic Creek lie within PRWI. North Branch Chopawamsik serves as the boundary between Prince William and Stafford Counties. A major impoundment of Chopawamsic Creek occurs as the stream exits the parks, forming the Breckenridge Reservoir, the drinking water reservoir for the base. Land use throughout this watershed is forested with military-related activity.

NCRN monitors six streams in PRWI: North Branch Chopawamsic Creek is located on the downstream of MCB-1, just off Quantico Marine Corps Base Property; Middle Branch Chopawamsic Creek on the downstream of MCB-1, just off Base property; North Fork Quantico Creek upstream of Pyrite Mine Road; South Fork Quantico Creek along South Valley Trail at the former USGS Gauging Station; Mary Bird Branch along South Valley Trail, approximately 75 meters upstream of its confluence with South Fork Quantico Creek; Sow Run downstream of Scenic Drive, approximately 10 meters upstream of its confluence with South Fork Quantico Creek.

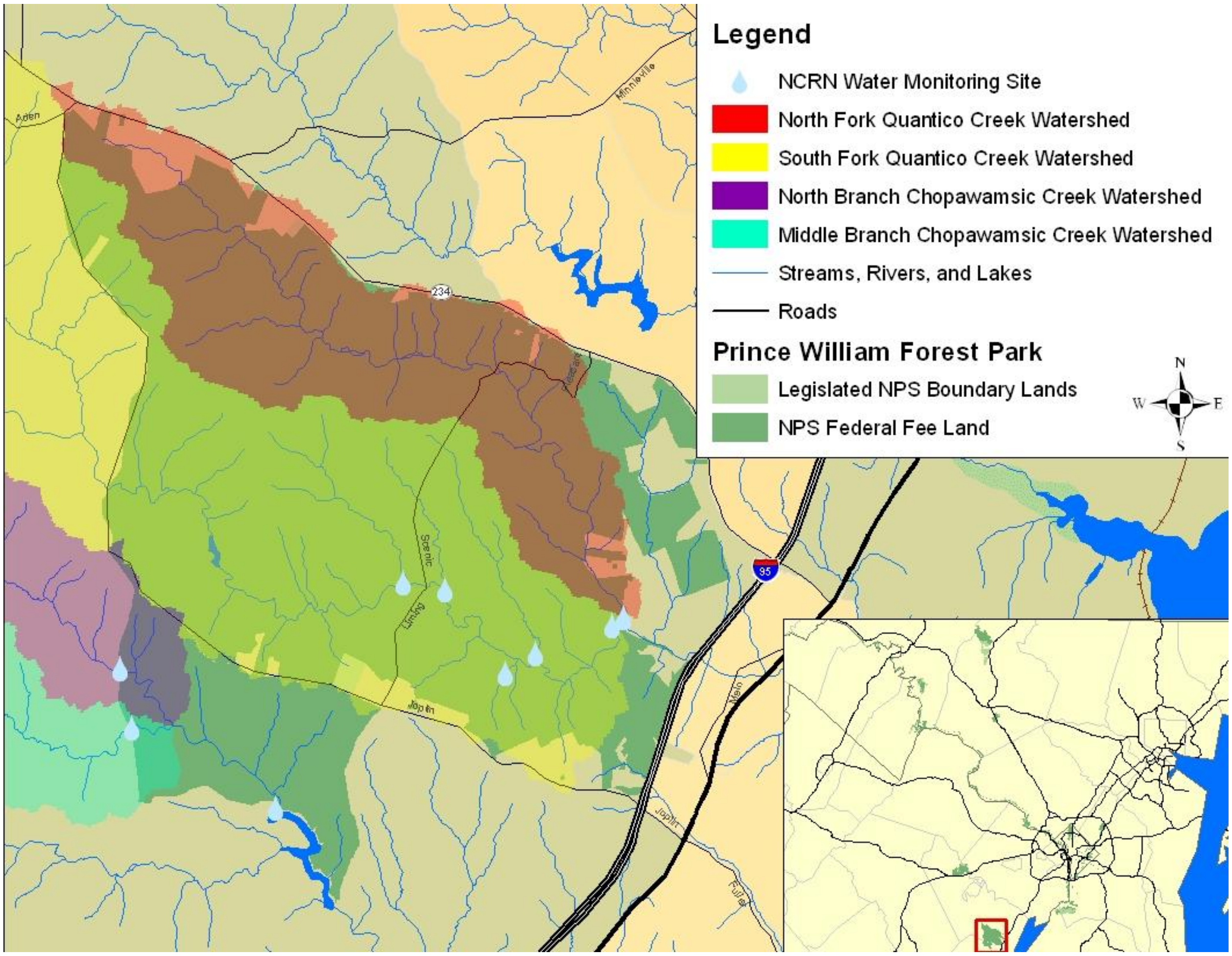

Figure 24: Relationship of PRWI stream monitoring sites to their watersheds and the park boundary

Table 14: Date range, number of site visits, and data range for the information covered in this report.

Characteristic	Units	Period of Record	Count	Min.	Max.
Mary Bird Branch					
ANC	μeq/L	6/13/2005 - 9/27/2006	12	200	398
DO (mg/L)	mg/l	6/13/2005 - 9/27/2006	13	2.88	10
Nitrate	mg/l	6/13/2005 - 9/27/2006	13	0.2	0.5
Nitrogen, Ammonia	mg/l	6/13/2005 - 9/27/2006	13	-0	0.07
pH	None	6/13/2005 - 7/27/2006	12	6.46	10.4
Phosphorus	mg/l	6/13/2005 - 9/27/2006	13	0.25	5.87
Specific conductance	μS/cm	6/13/2005 - 9/27/2006	13	41.9	62.9
Middle Branch Chopawamsic					
ANC	μeq/L	6/13/2005 - 9/27/2006	12	202	528
DO (mg/L)	mg/l	6/13/2005 - 9/27/2006	14	1.8	11.6
Nitrate	mg/l	6/13/2005 - 9/27/2006	14	0.2	1.8
Nitrogen, Ammonia	mg/l	6/13/2005 - 9/27/2006	14	-0	0.17
pH	None	6/13/2005 - 9/27/2006	14	5.88	6.9
Phosphorus	mg/l	6/13/2005 - 9/27/2006	14	0.19	5.33
Specific conductance	μS/cm	6/13/2005 - 9/27/2006	14	20.6	80.4
North Fork Quantico Creek					
ANC	μeq/L	6/13/2005 - 9/27/2006	14	220	744
DO (mg/L)	mg/l	6/13/2005 - 9/27/2006	15	3.54	11.4
Nitrate	mg/l	6/13/2005 - 9/27/2006	15	0.1	0.4
Nitrogen, Ammonia	mg/l	6/13/2005 - 9/27/2006	15	-0	0.12
pH	None	6/13/2005 - 9/27/2006	15	6.44	7.25
Phosphorus	mg/l	6/13/2005 - 9/27/2006	15	0.08	5.89
Specific conductance	μS/cm	6/13/2005 - 9/27/2006	15	55.8	367
North Branch Chopawamsic					
ANC	μeq/L	6/13/2005 - 9/27/2006	12	208	776
DO (mg/L)	mg/l	6/13/2005 - 9/27/2006	14	2.86	11.8
Nitrate	mg/l	6/13/2005 - 9/27/2006	14	0.2	1.9
Nitrogen, Ammonia	mg/l	6/13/2005 - 9/27/2006	14	-0	0.09
pH	None	6/13/2005 - 9/27/2006	14	6.13	6.88
Phosphorus	mg/l	6/13/2005 - 9/27/2006	14	0.09	0.89
Specific conductance	μS/cm	6/13/2005 - 9/27/2006	14	23.8	60.2
South Fork Quantico Creek					
ANC	μeq/L	6/13/2005 - 9/28/2006	12	200	434
DO (mg/L)	mg/l	6/13/2005 - 9/28/2006	14	4.05	11.1
Nitrate	mg/l	6/13/2005 - 9/28/2006	14	0.2	0.4
Nitrogen, Ammonia	mg/l	6/13/2005 - 9/28/2006	14	-0	0.6
pH	None	6/13/2005 - 9/28/2006	14	6.44	13
Phosphorus	mg/l	6/13/2005 - 9/28/2006	14	0.04	5.21
Specific conductance	μS/cm	6/13/2005 - 9/28/2006	14	35	70.3
Sow Run					
ANC	μeq/L	6/13/2005 - 9/27/2006	11	204	672

DO (mg/L)	mg/l	6/13/2005 - 9/27/2006	15	1.38	11.7
Nitrate	mg/l	6/13/2005 - 9/27/2006	15	0.2	0.5
Nitrogen, Ammonia	mg/l	6/13/2005 - 9/27/2006	15	-0	0.07
pH	None	6/13/2005 - 9/27/2006	15	6.51	7.31
Phosphorus	mg/l	6/13/2005 - 9/27/2006	15	0.12	4.95
Specific conductance	µS/cm	6/13/2005 - 9/27/2006	15	20.9	49.1

Table 15: Condition assessment and significance for site visits to Prince William Streams 2005 – 2006.

Stream	ANC	DO	NH_3	NO_3	pH	PO_4	SC
Mary Bird Branch	0	31	0	0	8	100	0
Middle Branch Chopawamsic	0	29	0	0	0	100	0
North Fork Quantico Creek	0	20	0	0	0	91	0
North Branch Chopawamsic	0	29	0	0	0	92	0
South Fork Quantico Creek	0	7	0	0	7	92	0
Sow Run	0	13	0	0	0	100	0

pH tends to be at the low end of desirable condition in PRWI streams with Chopawamsic tributaries close to the lower threshold. This is especially of concern due to the lower ANC in the park and the recent realization that streams in Shenandoah are acidified to the point o losing native trout populations. There are 2 incidents of unusually high pH, South Fork Quantico Creek in September 2006 and Mary Bird Branch in August 2006 (see figure 26).

All streams exceed PO4 almost all of the time (see figure 28). There is no known source within the park. And the Marine Corps Base is required to maintain the headwaters in pristine condition. Potential sources of PO4 need to be fully investigated.

Dissolved oxygen tends to be low in the parks in late summer and early spring (see figure 31).

These measures constitute a snap shot of stream conditions in time and space, and are not representative of quality over a 24 hour period. All of these measures are influenced to a certain degree by biological activity which follows diurnal and seasonal patterns of temperature and sunlight. There is not yet enough data to identify seasonal patterns or trends.

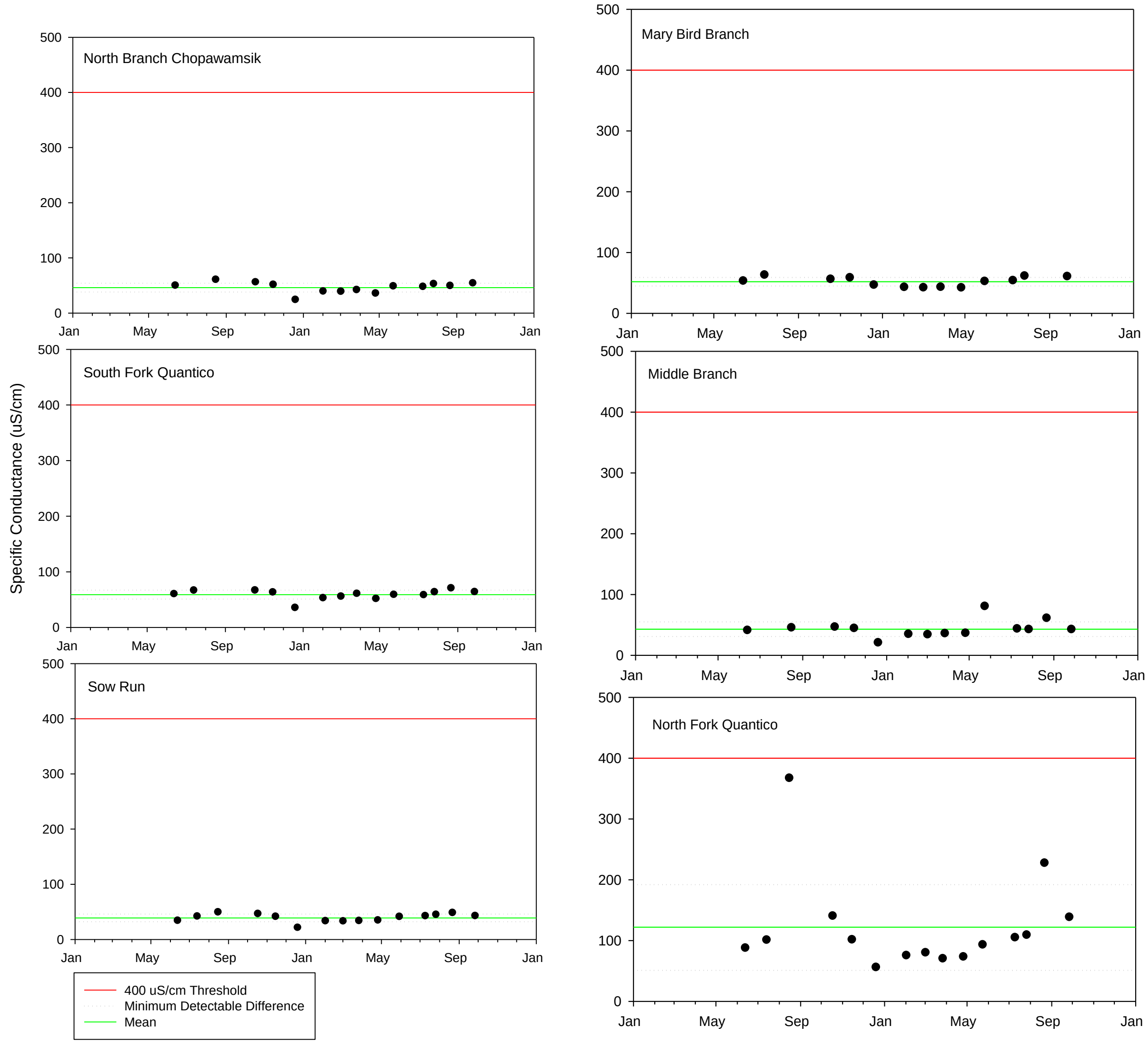

Figure 25: Specific Conductance in Prince William Forest Park streams 2005 - 2006.

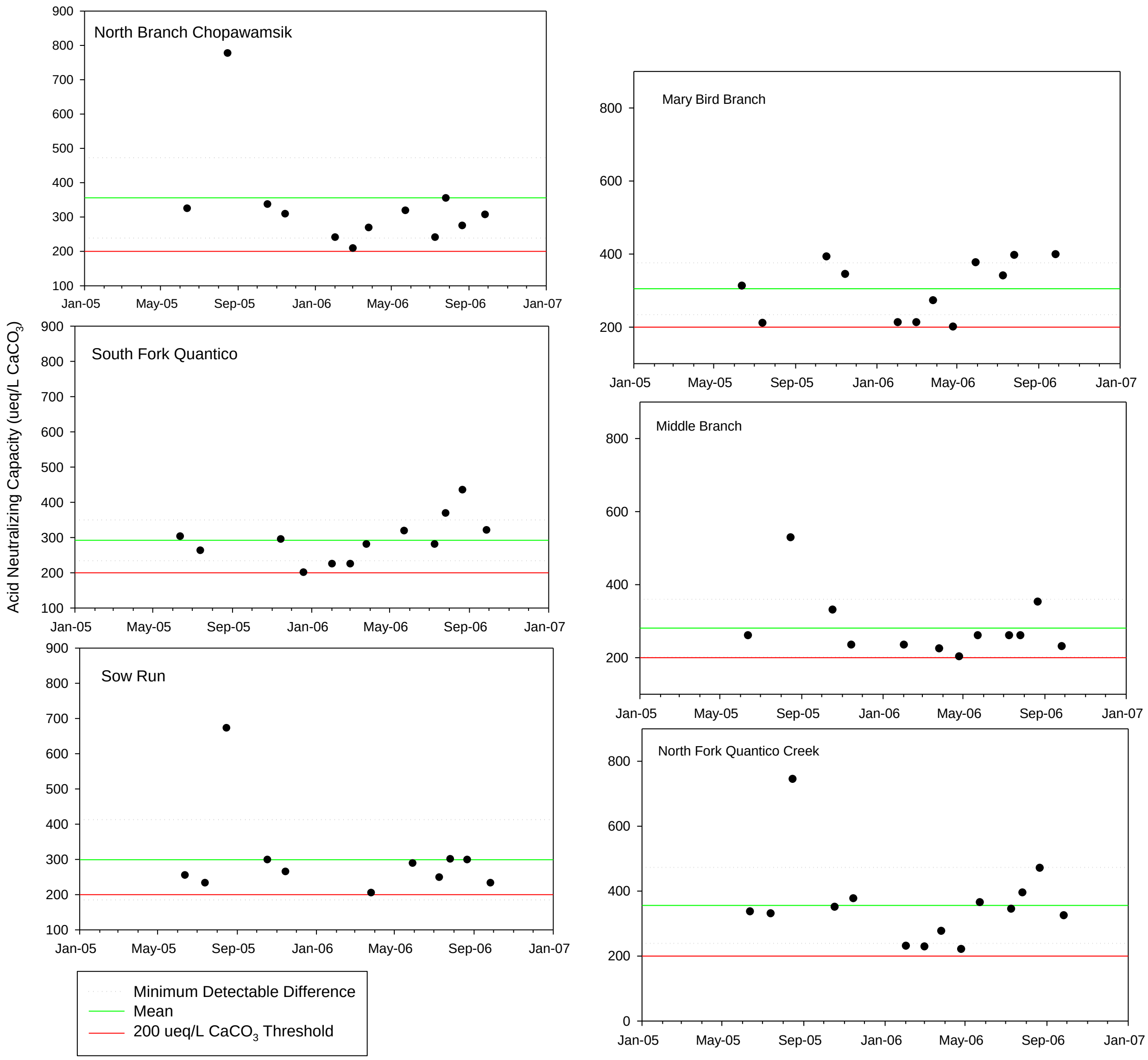

Figure 26: ANC in Prince William Forest Park streams 2005 - 2006.

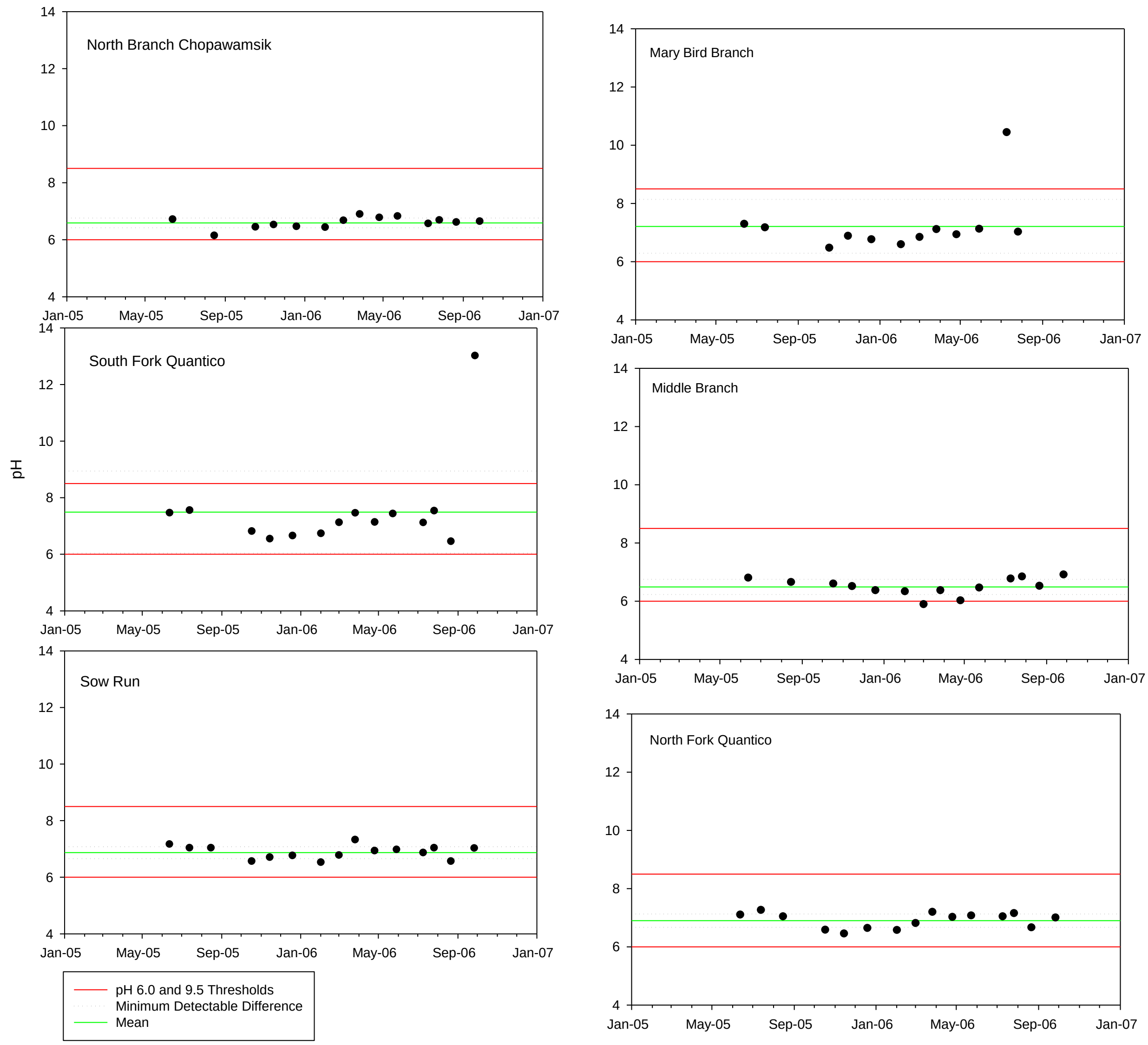

Figure 27: pH in Prince William Forest Park streams 2005 - 2006.

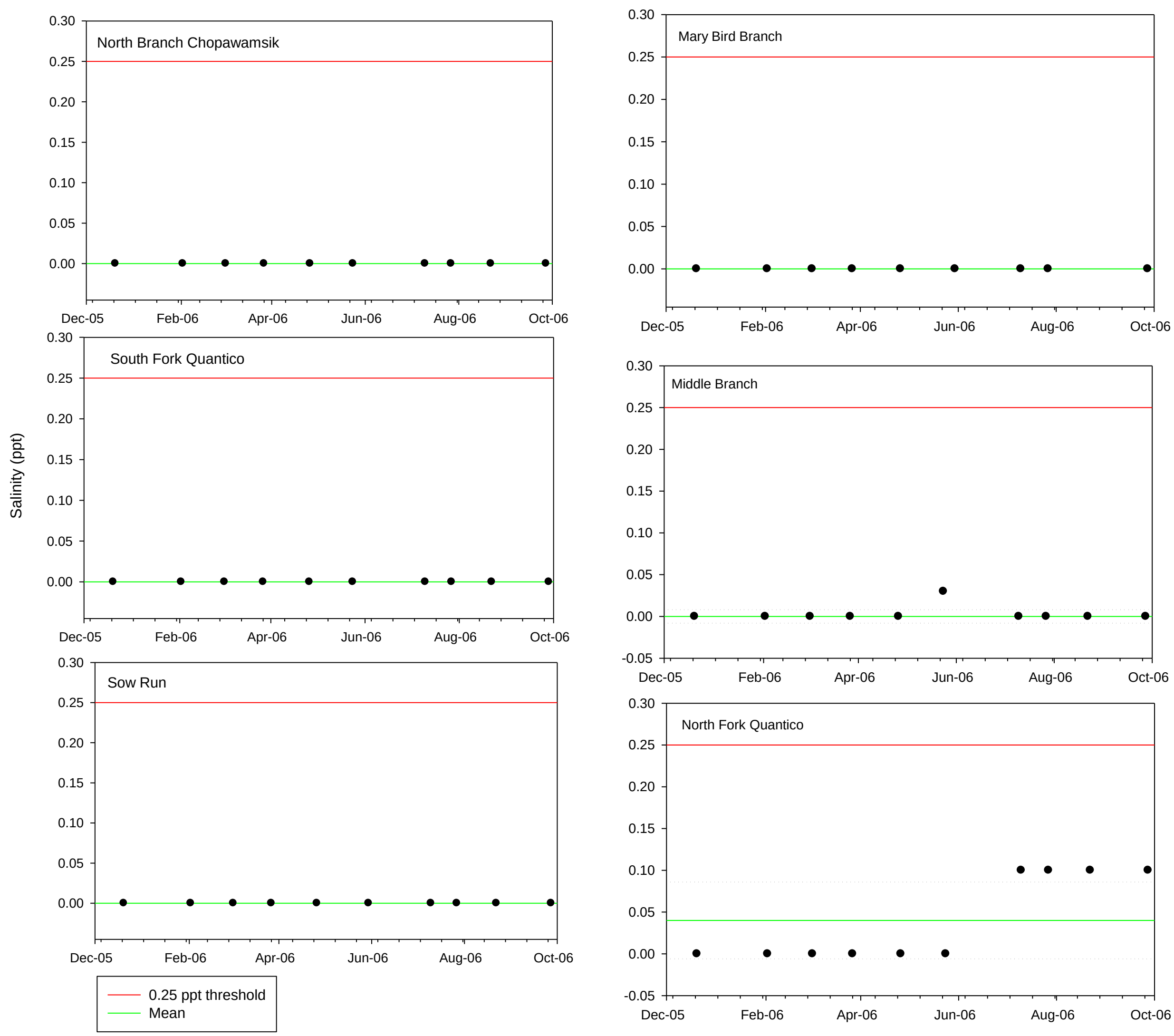

Figure 28: Salinity in Prince William Forest Park streams 2005 - 2006.

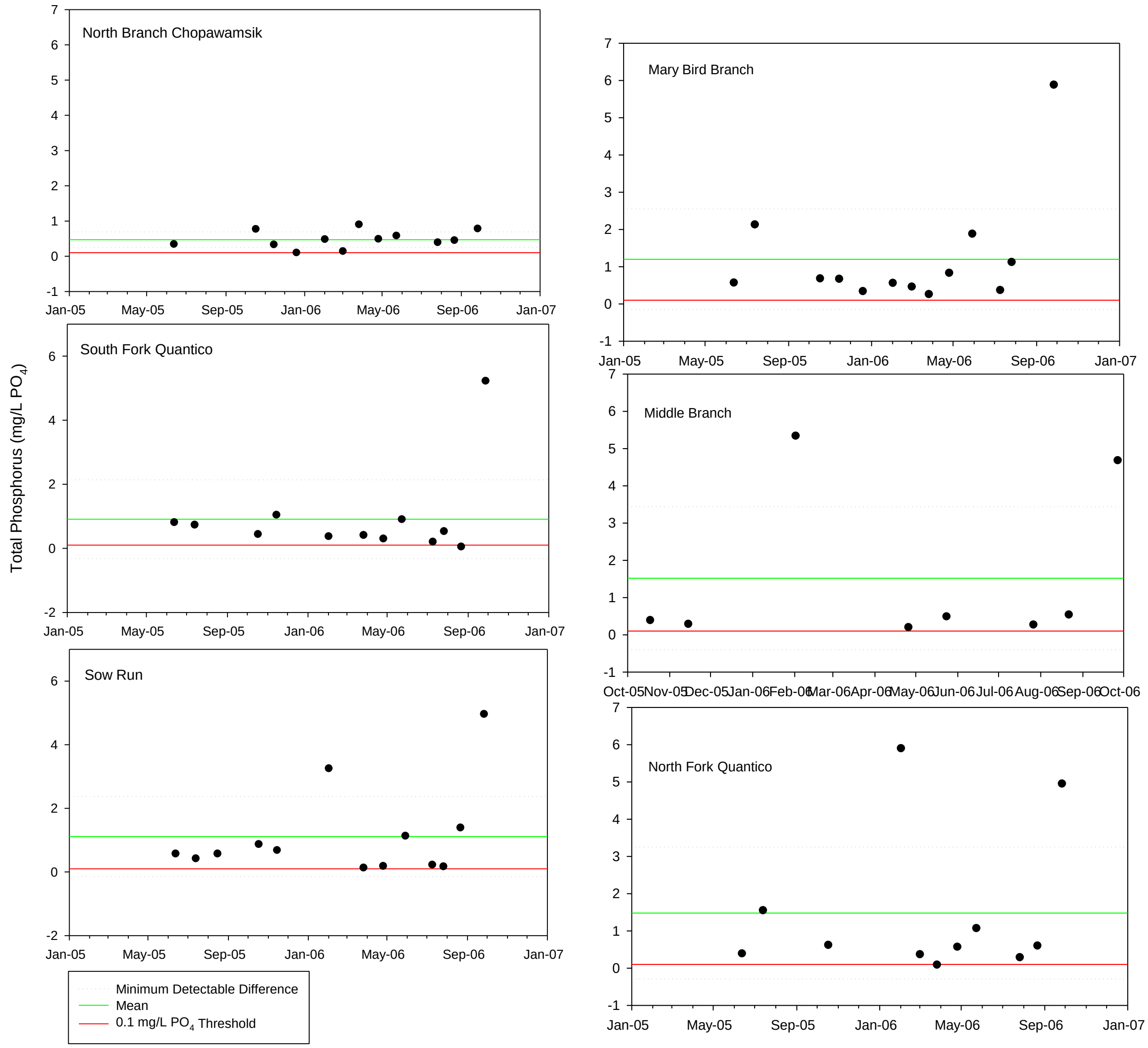

Figure 29: Total Phosphorus in Prince William Forest Park streams 2005 - 2006.

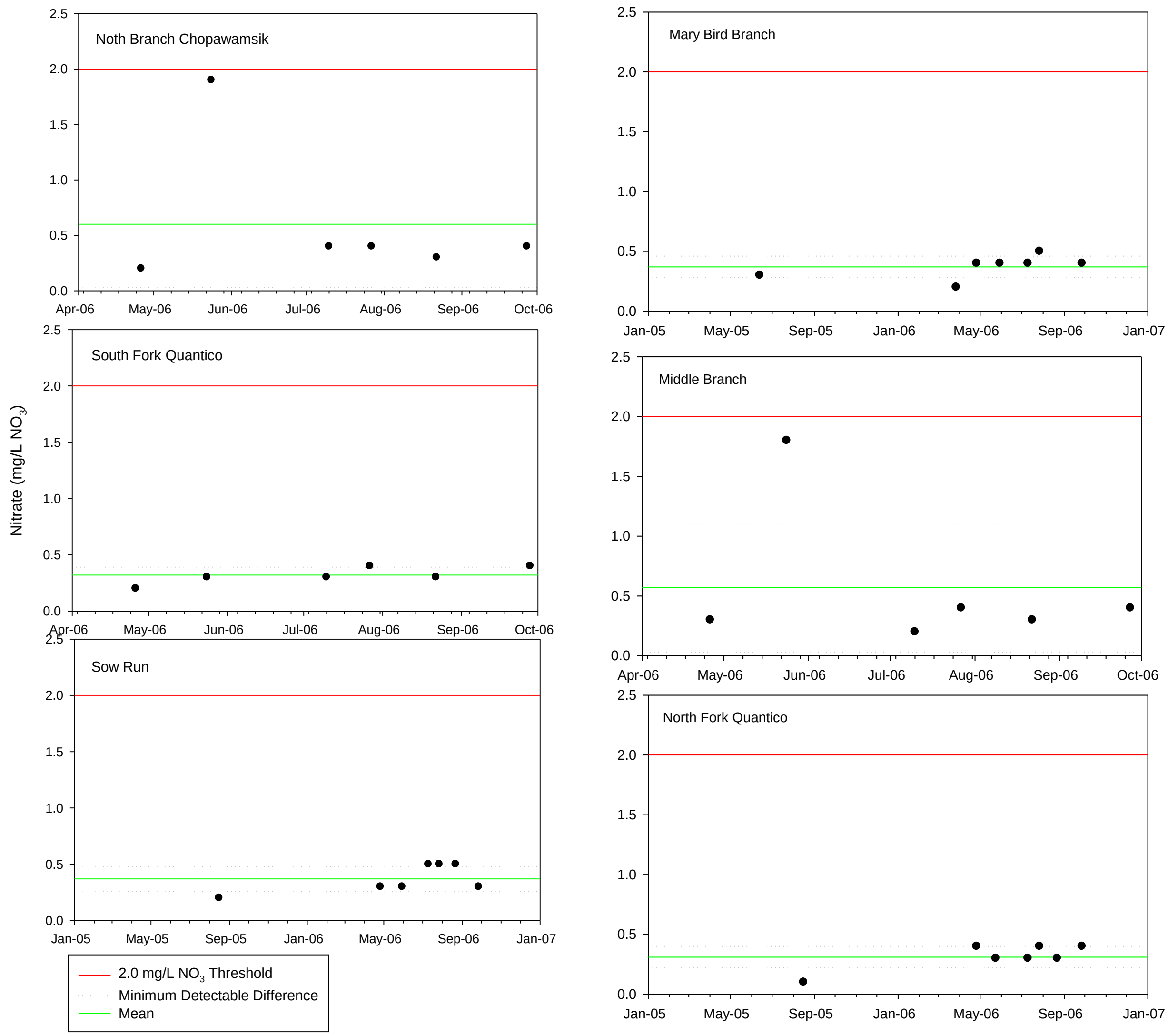

Figure 30: Nitrate in Prince William Forest Park streams 2005 - 2006

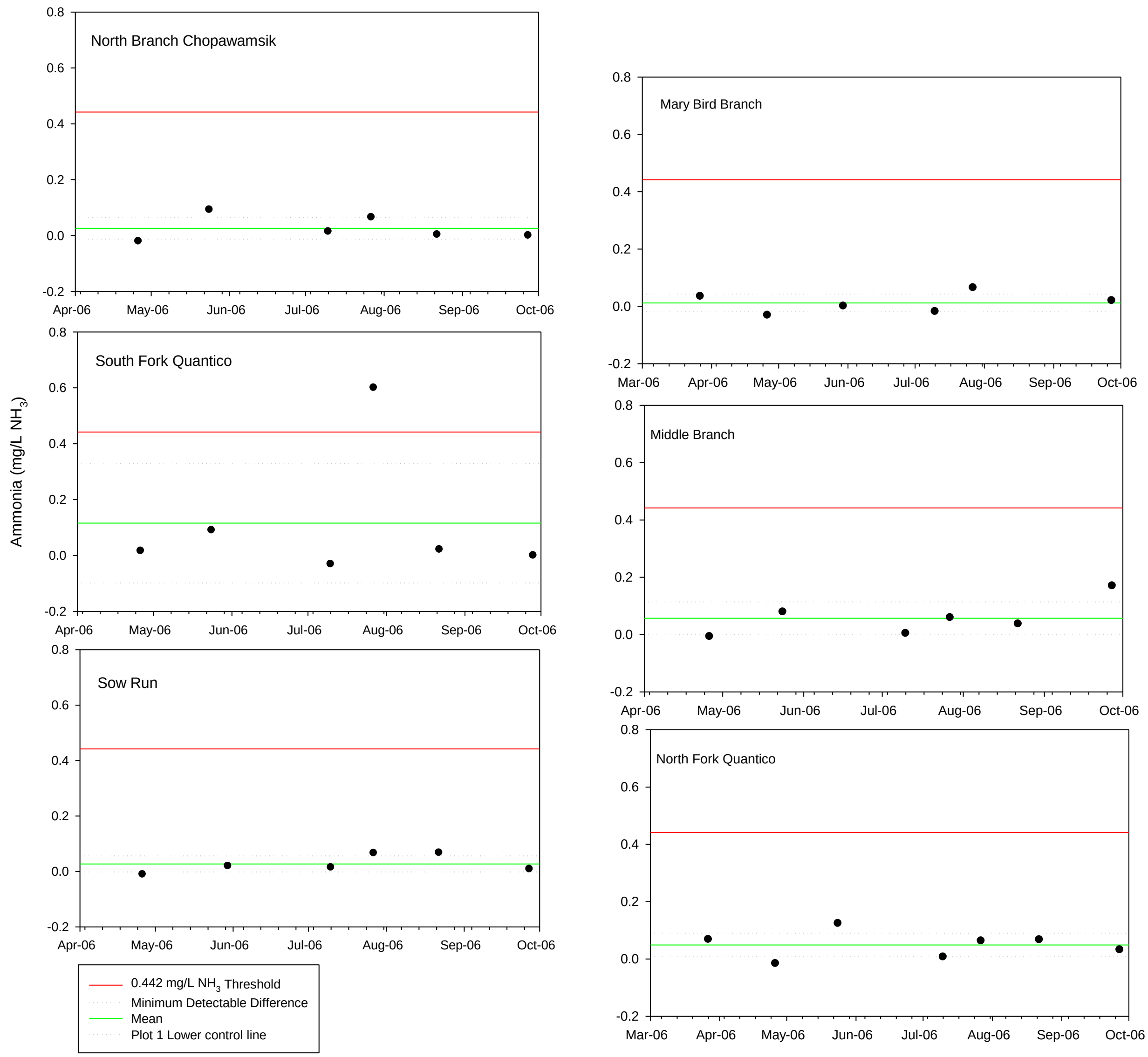

Figure 31: Ammonia in Prince William Forest Park streams 2005 - 2006.

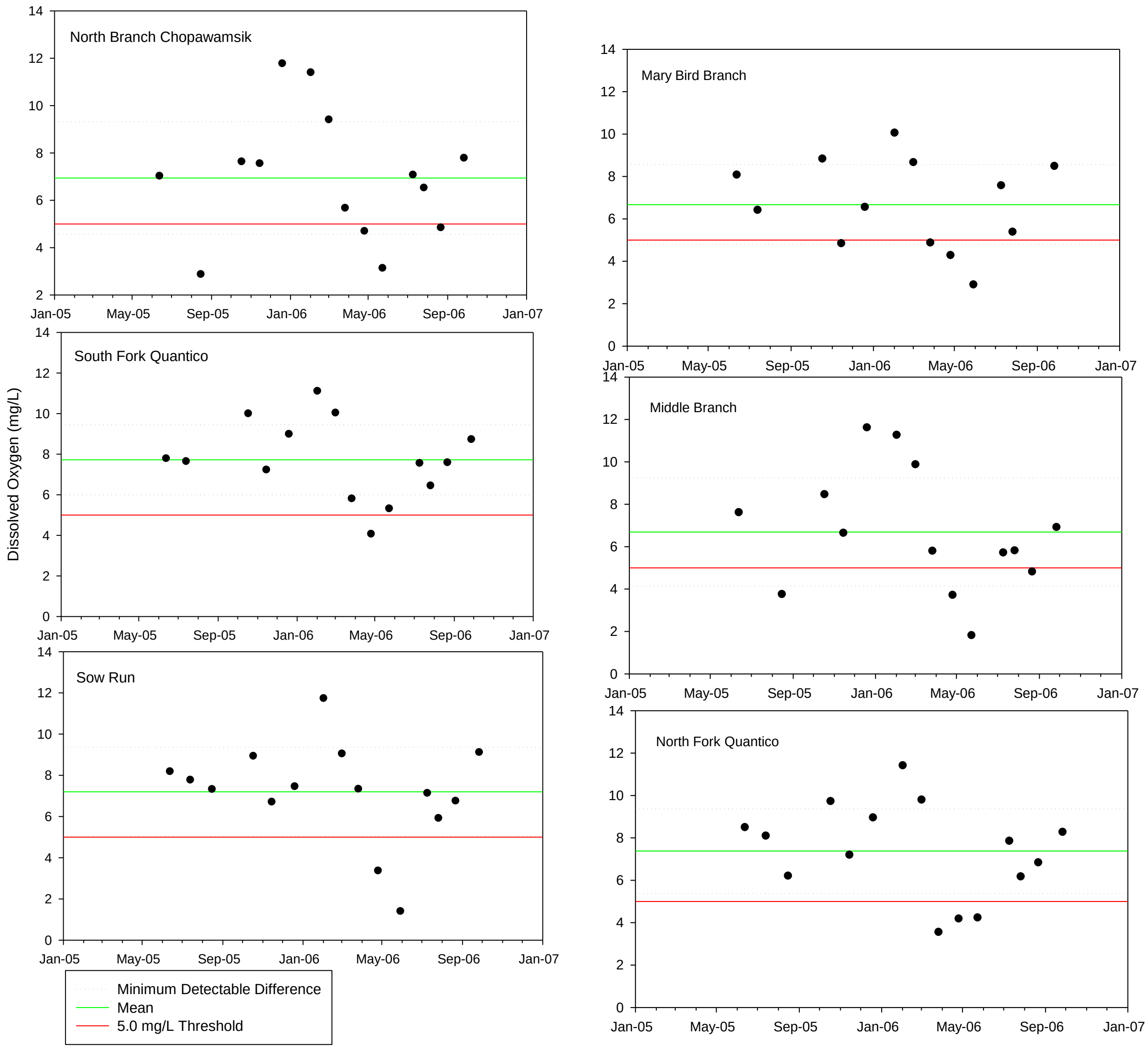

Figure 32: Dissolved Oxygen in Prince William Forest Park streams 2005 - 2006.

Rock Creek Park (ROCR)

Rock Creek Park, comprised of approximately 2,100 acres of park land, is located within the Piedmont and Coastal Plain Physiographic Province within Washington, DC. The park is named for Rock Creek, the focal stream which flows through the center of the park. Several tributaries feed into Rock Creek, including some which are almost entirely piped. Historically, land use in the park was primarily residential, with some industry in the form of mills. Today, the park is mostly forested, but is surrounded by dense urban land use.

The park is located within the Potomac River drainage basin, and the greater Chesapeake Bay watershed. More specifically, ROCR is part of the Middle Potomac-Anacostia-Occoquan watershed (USGS hydrologic unit 02070010). Locally, the Rock Creek basin drains the core area of the park; however, some of the satellite locations are drained by smaller streams that empty directly into either the Chesapeake and Ohio Canal or the Potomac River, such as Palisades Creek and Foundry Branch. Rock Creek originates near Laytonsville, in Montgomery County, MD. Approximately 10 miles of its total length of 33 miles are located within the District of Columbia. Rock Creek becomes a fourth-order stream at the confluence of Rock Creek with the North Branch of Rock Creek, north of Rockville, Maryland. It remains a fourth-order stream for the remainder of its length. Except for the narrow extension of parkland into Maryland that is under Montgomery County administration, Rock Creek Park represents a largely isolated natural system surrounded by urban areas, which have significantly impacted the park. These effects include flooding and pollution in park streams, introductions of invasive non-native species into natural areas, extirpations or reductions of sensitive native species, and the artificial inflation of a few native species' populations adversely that affect other native plants and wildlife.

NCRN monitors ten sites, along Broad Branch, Fenwick Branch, Hazen Creek, Luzon Branch, Palisades Creek, Pinehurst Branch, Piney Branch, Soapstone Valley Stream, and two sites on Rock Creek. The two sites on Rock Creek are located upstream and downstream of tributaries that are sampled. All of the other streams are tributaries to Rock Creek, except for Palisades Creek, which is part of a satellite park.

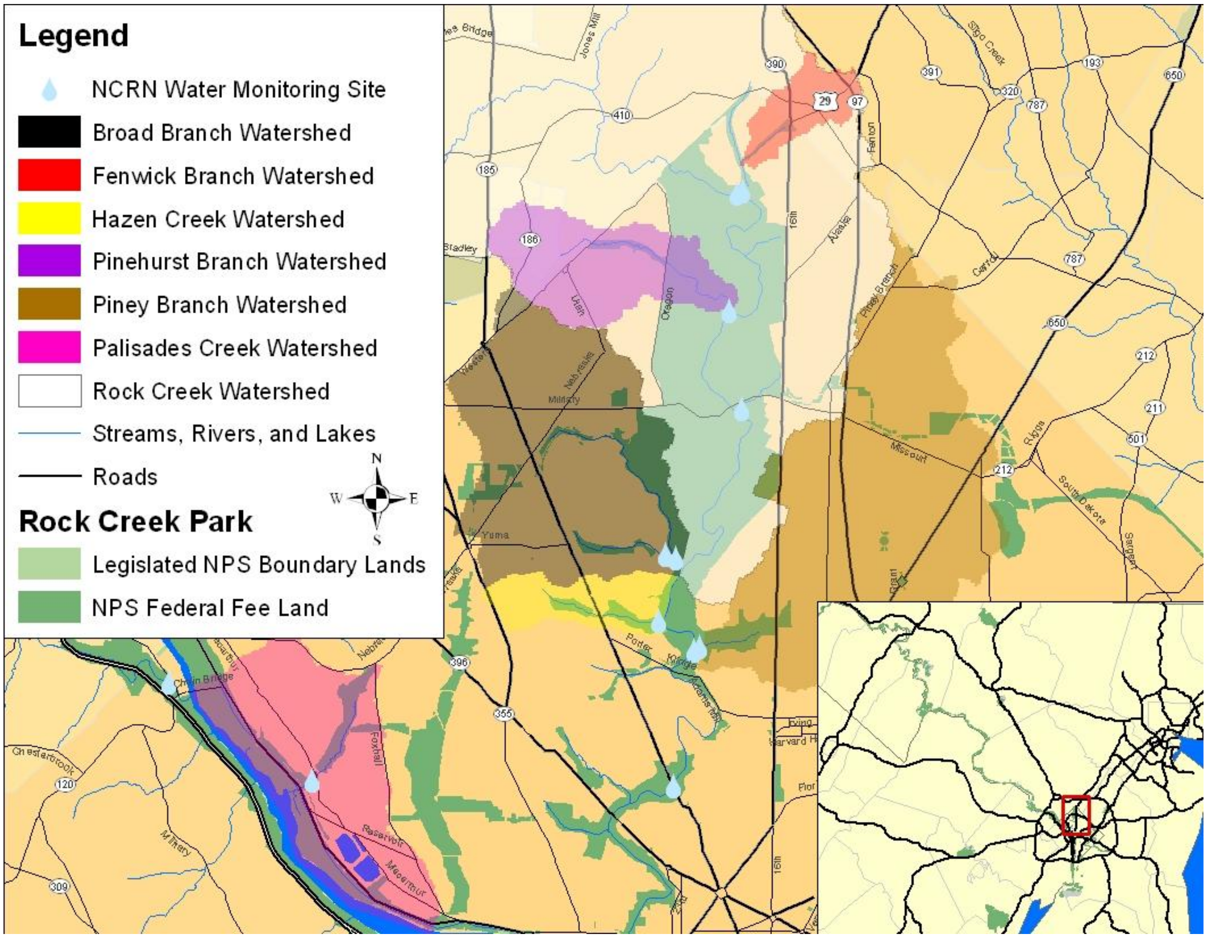

Figure 33: Relationship of the stream monitoring sites to their watersheds and the park boundary

Table 16: Date range, number of site visits, and data range for the information covered in this report.

Characteristic	Units	Period of Record	Count	Min.	Max.
Broad Branch					
ANC	μeq/L	6/27/2005 - 9/12/2006	13	896	2256
DO (mg/L)	mg/l	6/27/2005 - 9/12/2006	13	2.63	13.54
Nitrate	mg/l	6/27/2005 - 9/12/2006	13	1.1	4.3
Nitrogen, Ammonia	mg/l	6/27/2005 - 9/12/2006	13	0	0.546
pH	None	6/27/2005 - 9/12/2006	13	7.56	8.89
Phosphorus	mg/l	6/27/2005 - 9/12/2006	13	0.14	5.16
Specific conductance	μS/cm	6/27/2005 - 9/12/2006	13	456.7	2299
Rock Creek 2					
ANC	μeq/L	6/27/2005 - 9/12/2006	13	544	1616
DO (mg/L)	mg/l	6/27/2005 - 9/12/2006	13	2.47	12.22
Nitrate	mg/l	6/27/2005 - 9/12/2006	13	0.6	3.1
Nitrogen, Ammonia	mg/l	6/27/2005 - 9/12/2006	13	0	0.515

pH	None	6/27/2005 - 9/12/2006	13	7.5	8.91
Phosphorus	mg/l	6/27/2005 - 9/12/2006	13	0.11	2.08
Specific conductance	µS/cm	6/27/2005 - 9/12/2006	13	384.2	2577
Fenwick Branch					
ANC	µeq/L	6/27/2005 - 8/3/2006	12	940	2432
DO (mg/L)	mg/l	6/27/2005 - 8/3/2006	12	1.31	12.78
Nitrate	mg/l	6/27/2005 - 8/3/2006	12	0.5	4.2
Nitrogen, Ammonia	mg/l	6/27/2005 - 8/3/2006	12	0	0.351
pH	None	6/27/2005 - 8/3/2006	12	7.13	7.77
Phosphorus	mg/l	6/27/2005 - 8/3/2006	12	0.23	2.35
Specific conductance	µS/cm	6/27/2005 - 8/3/2006	12	358	4168
Hazen Creek					
ANC	µeq/L	10/4/2005 - 9/12/2006	12	1288	2440
DO (mg/L)	mg/l	10/4/2005 - 9/12/2006	12	2.14	12.2
Nitrate	mg/l	10/4/2005 - 9/12/2006	12	1.4	4.2
Nitrogen, Ammonia	mg/l	10/4/2005 - 9/12/2006	12	0	0.3
pH	None	10/4/2005 - 9/12/2006	12	7.51	8.48
Phosphorus	mg/l	10/4/2005 - 9/12/2006	12	0.06	2.84
Specific conductance	µS/cm	10/4/2005 - 9/12/2006	12	601	1737
Luzon Branch					
ANC	µeq/L	10/4/2005 - 9/12/2006	12	1160	1800
DO (mg/L)	mg/l	10/4/2005 - 9/12/2006	12	2.95	13.84
Nitrate	mg/l	10/4/2005 - 9/12/2006	12	0.9	6.5
Nitrogen, Ammonia	mg/l	10/4/2005 - 9/12/2006	12	0	0.36
pH	None	10/4/2005 - 9/12/2006	12	7.44	8.35
Phosphorus	mg/l	10/4/2005 - 9/12/2006	12	0.23	4.96
Specific conductance	µS/cm	10/4/2005 - 9/12/2006	12	480	3192
Palisades Creek					
ANC	µeq/L	11/8/2005 - 5/18/2006	5	920	1168
DO (mg/L)	mg/l	11/8/2005 - 5/18/2006	5	2.51	12.29
Nitrate	mg/l	11/8/2005 - 5/18/2006	5	2.9	6.3
Nitrogen, Ammonia	mg/l	11/8/2005 - 5/18/2006	5	0.032	0.032
pH	None	11/8/2005 - 5/18/2006	5	6.83	8.05
Phosphorus	mg/l	11/8/2005 - 5/18/2006	5	0.61	8.82
Specific conductance	µS/cm	11/8/2005 - 5/18/2006	5	567	667
Pinehurst Branch					
ANC	µeq/L	10/4/2005 - 9/12/2006	12	1272	2160
DO (mg/L)	mg/l	10/4/2005 - 9/12/2006	12	2.6	12
Nitrate	mg/l	10/4/2005 - 9/12/2006	12	0.3	4.1
Nitrogen, Ammonia	mg/l	10/4/2005 - 9/12/2006	12	0	0.188
pH	None	10/4/2005 - 9/12/2006	12	7.23	8.91
Phosphorus	mg/l	10/4/2005 - 9/12/2006	12	0.15	3.333
Specific conductance	µS/cm	10/4/2005 - 9/12/2006	12	391.5	1410
Piney Branch					
ANC	µeq/L	10/4/2005 - 9/12/2006	12	970	1872
DO (mg/L)	mg/l	10/4/2005 - 9/12/2006	12	2.96	11.63
Nitrate	mg/l	10/4/2005 - 9/12/2006	12	1.7	5.3
Nitrogen, Ammonia	mg/l	10/4/2005 - 9/12/2006	12	0	0.227

pH	None	10/4/2005 - 9/12/2006	12	7.42	8.44
Phosphorus	mg/l	10/4/2005 - 9/12/2006	12	0.06	1.59
Specific conductance	µS/cm	10/4/2005 - 9/12/2006	12	390	1170
Rock Creek 1					
ANC	µeq/L	6/27/2005 - 9/11/2006	13	552	1664
DO (mg/L)	mg/l	6/27/2005 - 9/11/2006	13	0.89	10.26
Nitrate	mg/l	6/27/2005 - 9/11/2006	13	0.7	3.9
Nitrogen, Ammonia	mg/l	6/27/2005 - 9/11/2006	12	0.004	0.466
pH	None	6/27/2005 - 9/11/2006	13	6.83	7.67
Phosphorus	mg/l	6/27/2005 - 9/11/2006	13	0.08	1.15
Specific conductance	µS/cm	6/27/2005 - 9/11/2006	13	320.7	2193
Soapstone Valley Stream					
ANC	µeq/L	11/3/2005 - 9/12/2006	11	1240	5800
DO (mg/L)	mg/l	11/3/2005 - 9/12/2006	11	2.58	13.71
Nitrate	mg/l	11/3/2005 - 9/12/2006	11	1.7	4.7
Nitrogen, Ammonia	mg/l	11/3/2005 - 9/12/2006	11	0	0.199
pH	None	11/3/2005 - 9/12/2006	11	7.41	8.945
Phosphorus	mg/l	11/3/2005 - 9/12/2006	11	0.31	2.66
Specific conductance	µS/cm	11/3/2005 - 9/12/2006	11	456.9	2171

The mean specific conductance, at all sites, exceeds the ecologic threshold, indicated by the Maryland MBSS Program, of 400 µS/cm. Spikes are observed in February 2006, with matching spikes in salinity. This is likely due to de-icing operations within the park and in the surrounding areas. Overall sources impacting specific conductance need to be identified.

pH close to 9 has been observed in Pinehurst Branch, Soapstone Valley Stream, Broad Branch, and Rock Creek at Edgewater Stables, and is most likely due to algal blooms.

As observed at nearly every site within the region, phosphorus vales exceed the threshold. While this is likely due, at ROCR, to heavy use of fertilizer additional sources of phosphorus require identification. Fertilizer is also the most likely cause of the high nitrate levels observed in ROCR waters.

Spikes in ammonia levels have been observed that exceed the threshold. This has occurred at various times throughout the year, and need additional investigation to determine sources. One potential source is leaks within the sewer system in DC and ROCR, which are usually mitigated within a months' time.

Drops in dissolved oxygen are observed in all sites, during the spring and summer months, for the most part. These exceedances are likely due to increased biological oxygen demand, especially during the decomposition that follows algal blooms.

These measures constitute a snap shot of stream conditions in time and space, and are not representative of quality over a 24 hour period. All of these measures are influenced to a certain degree by biological activity which follows diurnal and seasonal patterns of temperature and sunlight. There is not yet enough data to identify seasonal patterns or trends.

Table 17: Condition assessment and significance for site visits to ROCR Streams 2005 – 2006.

Stream	ANC	DO	NH_3	NO_3	pH	PO_4	SC
Broad Branch	0	15	13	54	15	100	92
Rock Creek 2	0	23	14	23	15	100	69
Fenwick Branch	0	42	0	50	0	100	92
Hazen Creek	0	33	0	58	0	92	100
Luzon Branch	0	33	0	83	0	83	92
Palisades Creek	0	40	0	100	0	100	100
Pinehurst Branch	0	25	0	42	8	100	92
Piney Branch	0	33	0	83	0	82	92
Rock Creek 1	0	46	11	31	0	89	54
Soapstone Valley Stream	0	27	0	64	18	100	100

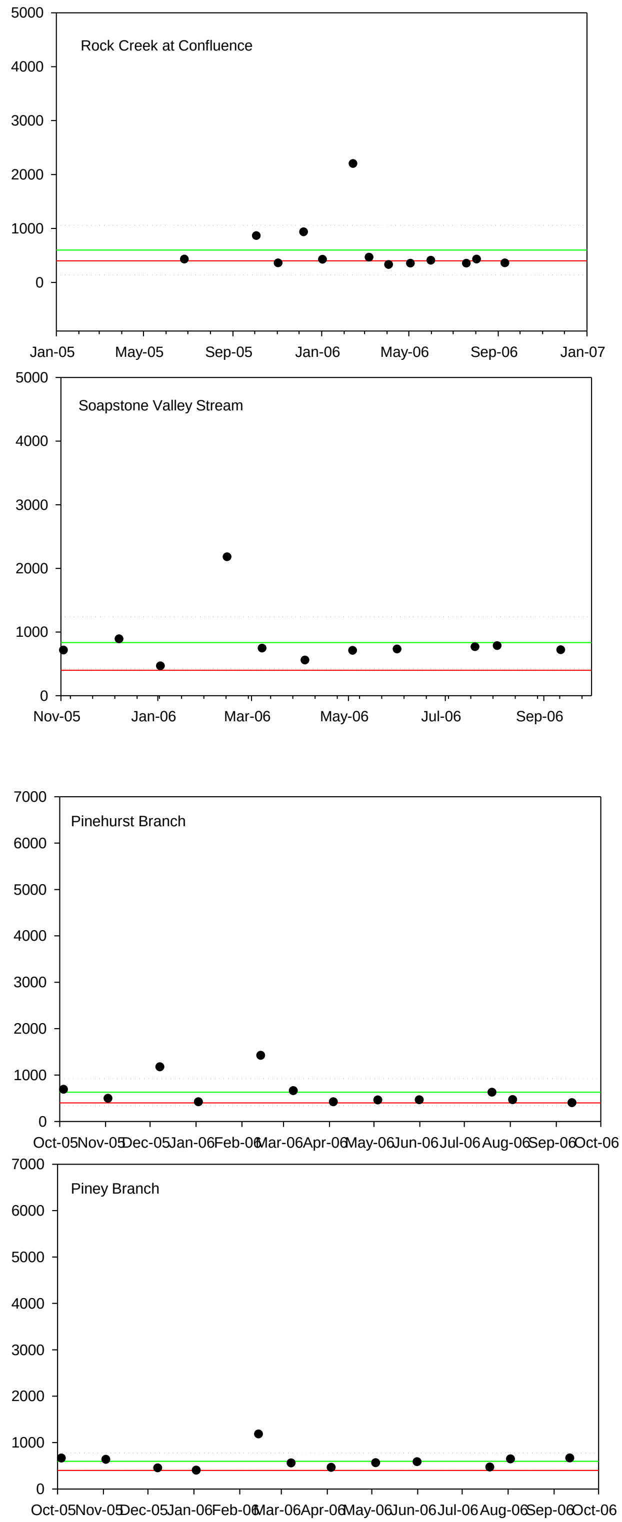

Figure 34: Specific Conductance in Rock Creek, Soapstone Valley Stream, Pinehurst Branch, and Piney Branch 2005-2006.

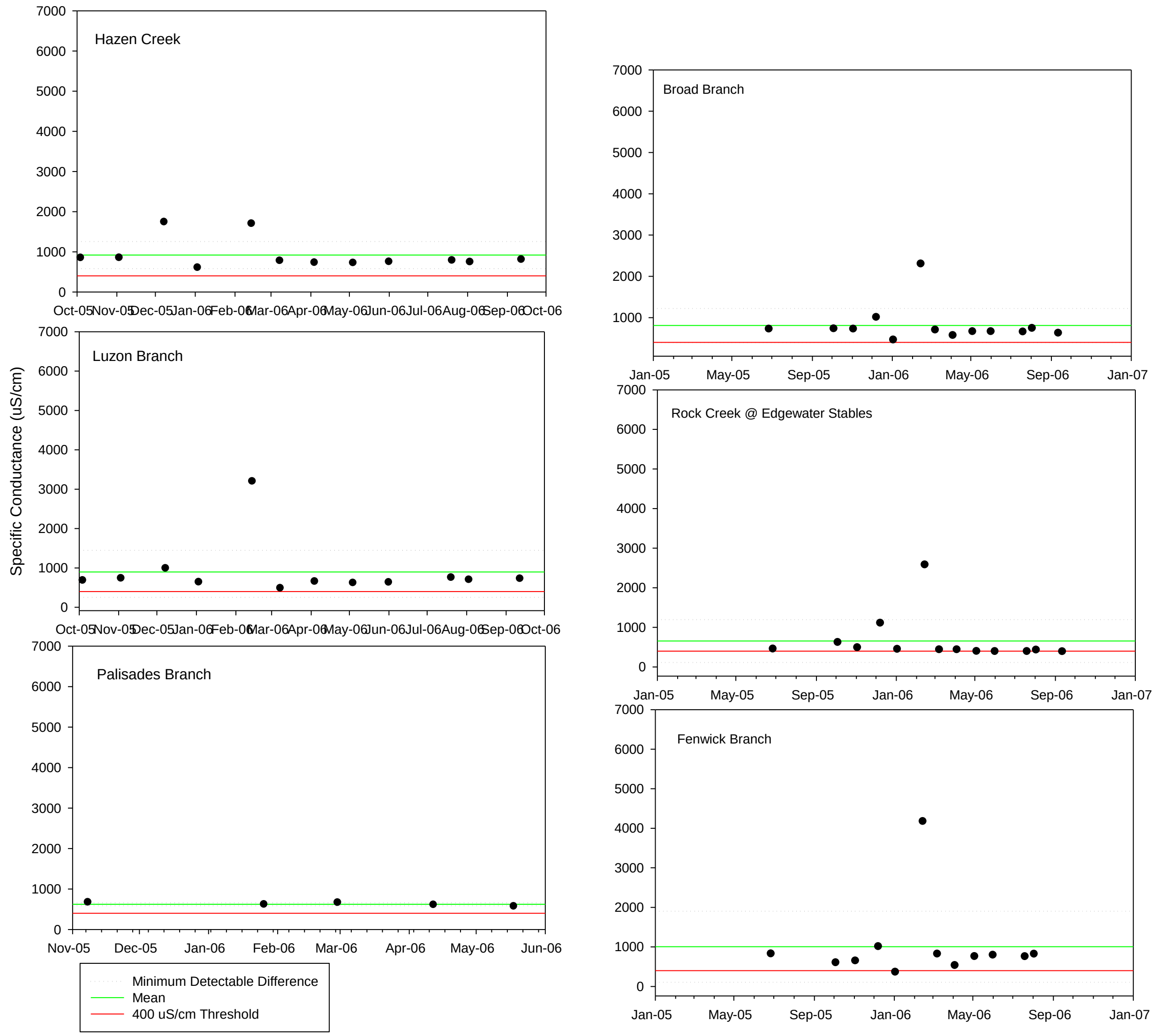

Figure 35: Specific Conductance in Hazen Creek, Luzon Branch, Palisades Branch, Broad Branch, Rock Creek, and Fenwick Branch 2005-2006.

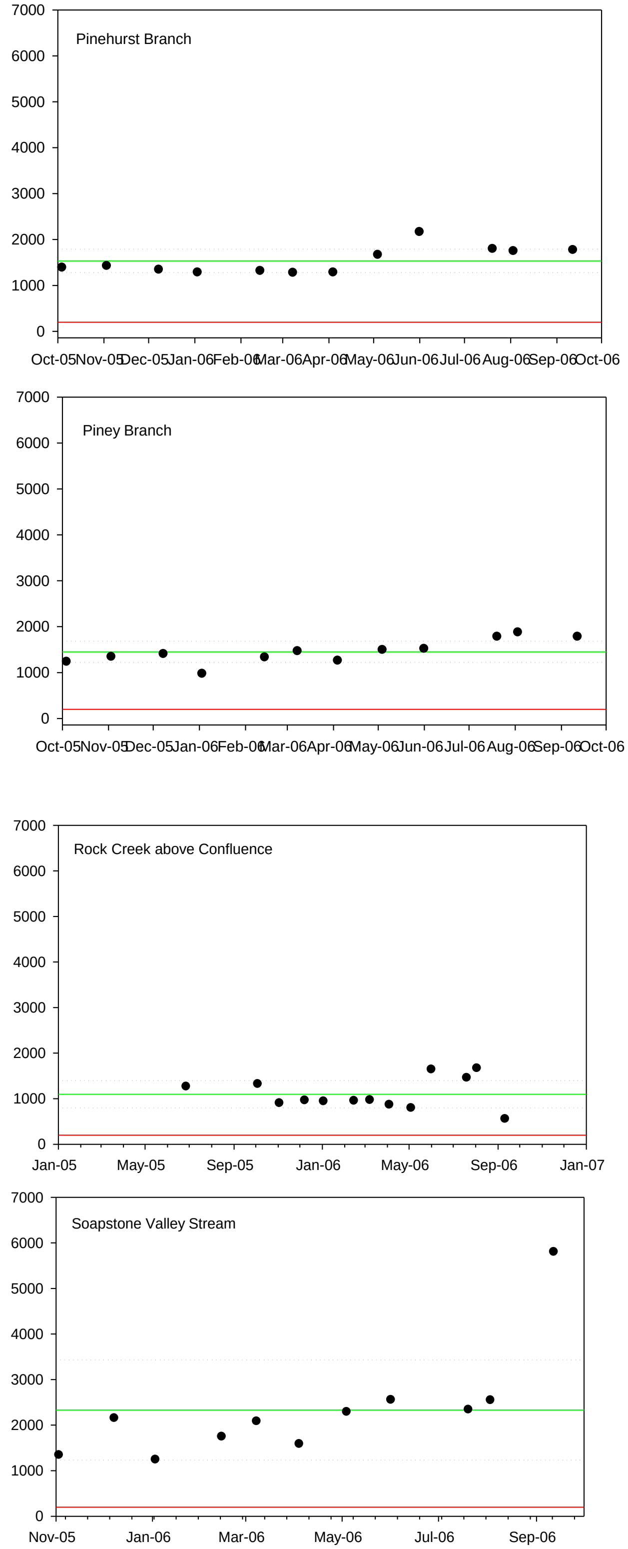

Figure 36: ANC in Rock Creek, Soapstone Valley Stream, Pinehurst Branch, and Piney Branch 2005-2006.

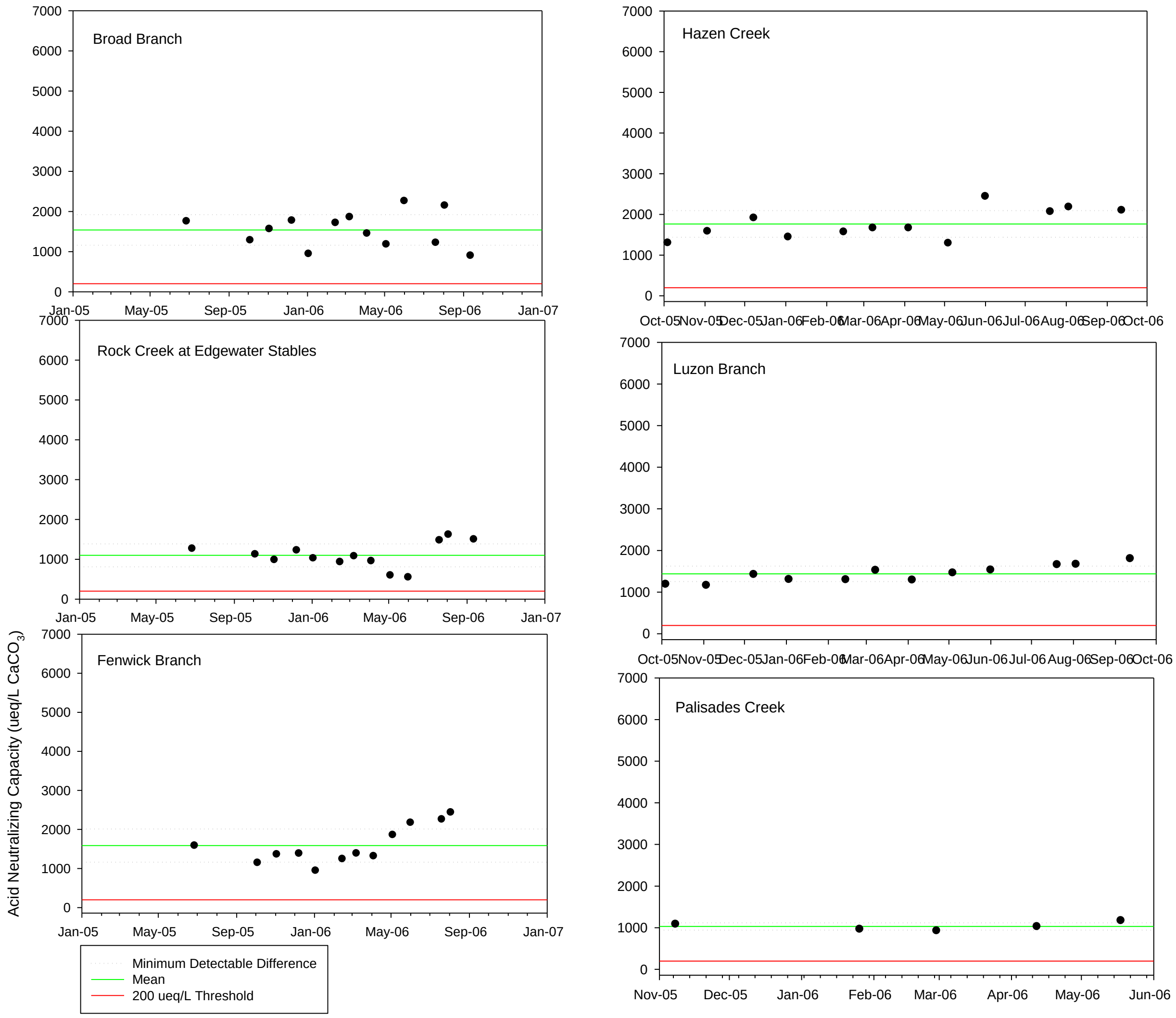

Figure 37: ANC in Hazen Creek, Luzon Branch, Palisades Branch, Broad Branch, Rock Creek, and Fenwick Branch 2005-2006.

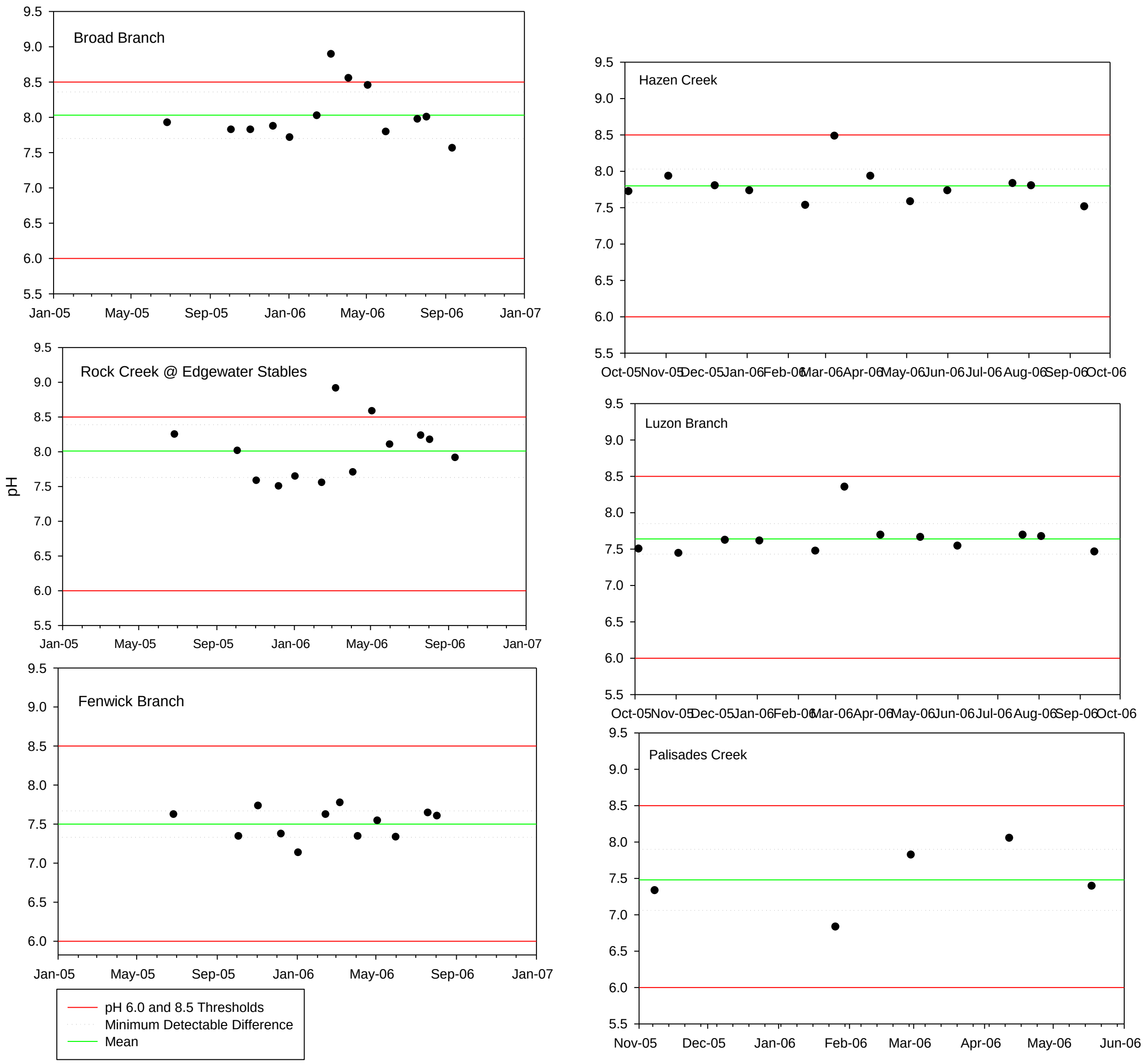

Figure 38: pH in Hazen Creek, Luzon Branch, Palisades Branch, Broad Branch, Rock Creek, and Fenwick Branch 2005-2006

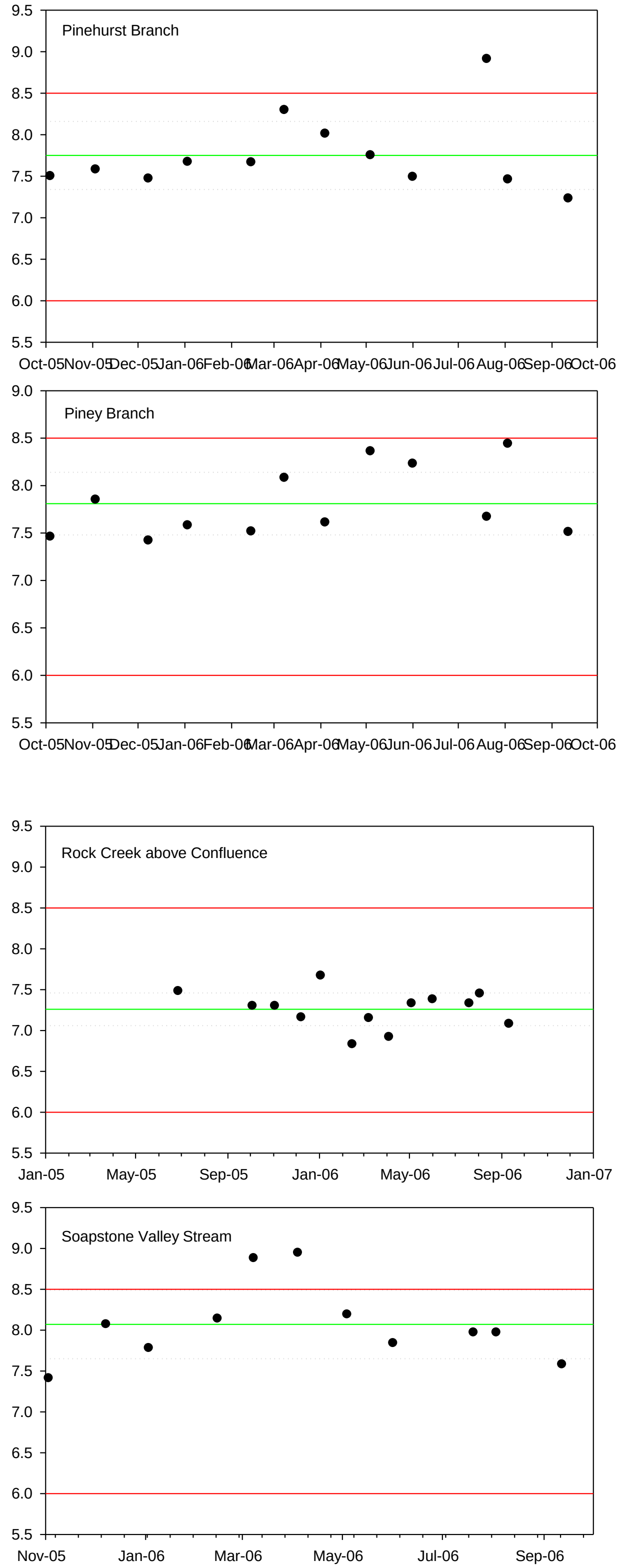

Figure 39: pH in Rock Creek, Soapstone Valley Stream, Pinehurst Branch, and Piney Branch 2005-2006.

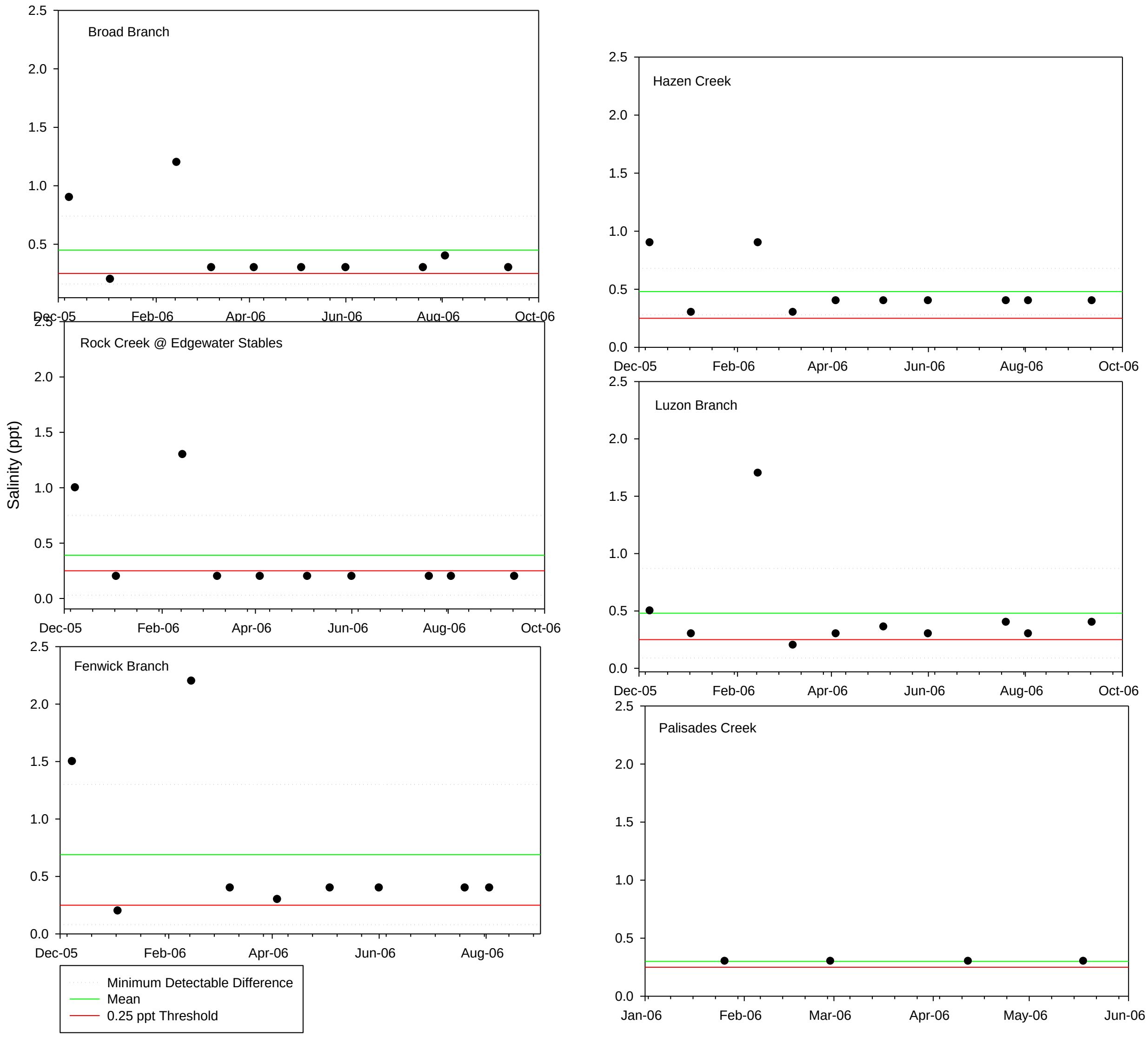

Figure 40: Salinity in Hazen Creek, Luzon Branch, Palisades Branch, Broad Branch, Rock Creek, and Fenwick Branch 2005-2006.

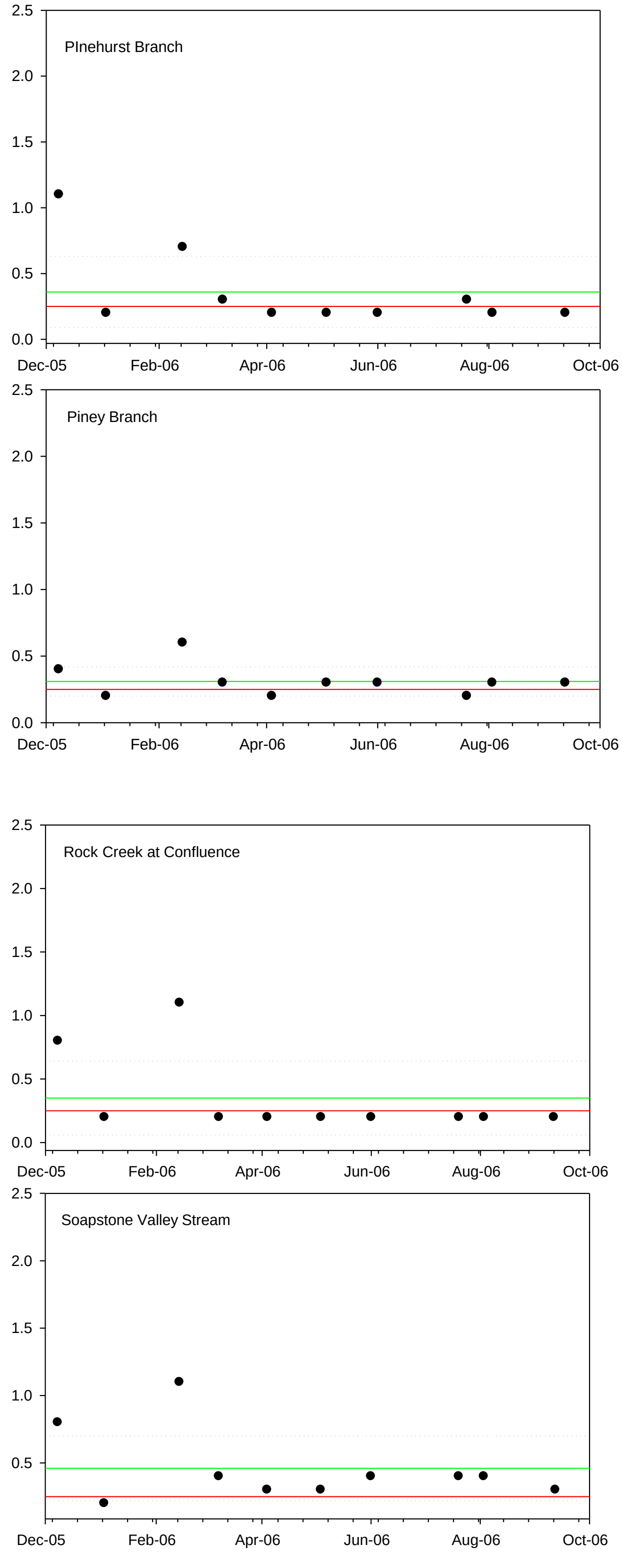

Figure 41: Salinity in Rock Creek, Soapstone Valley Stream, Pinehurst Branch, and Piney Branch 2005-2006.

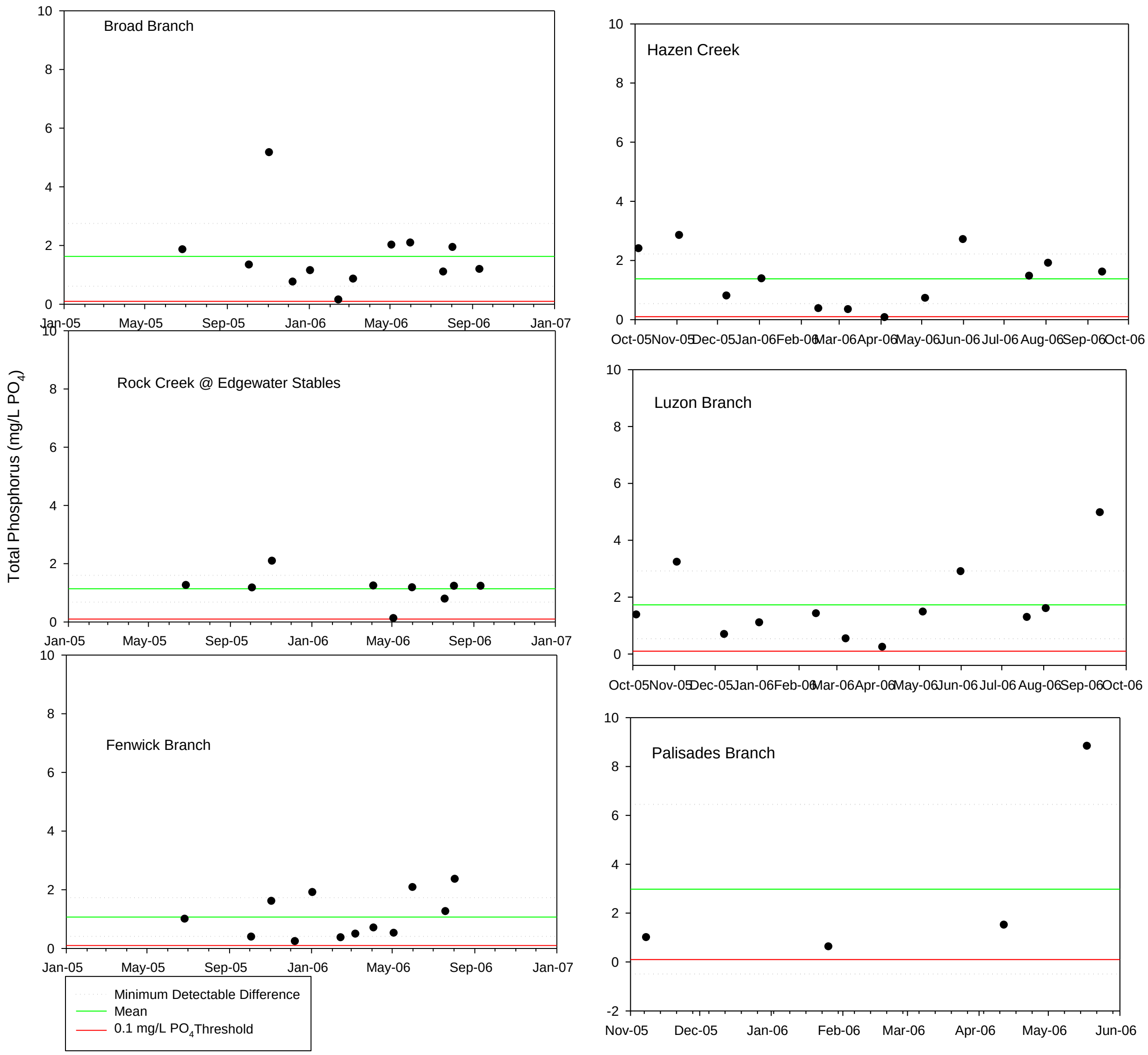

Figure 42: Total Phosphorus in Hazen Creek, Luzon Branch, Palisades Branch, Broad Branch, Rock Creek, and Fenwick Branch 2005-2006.

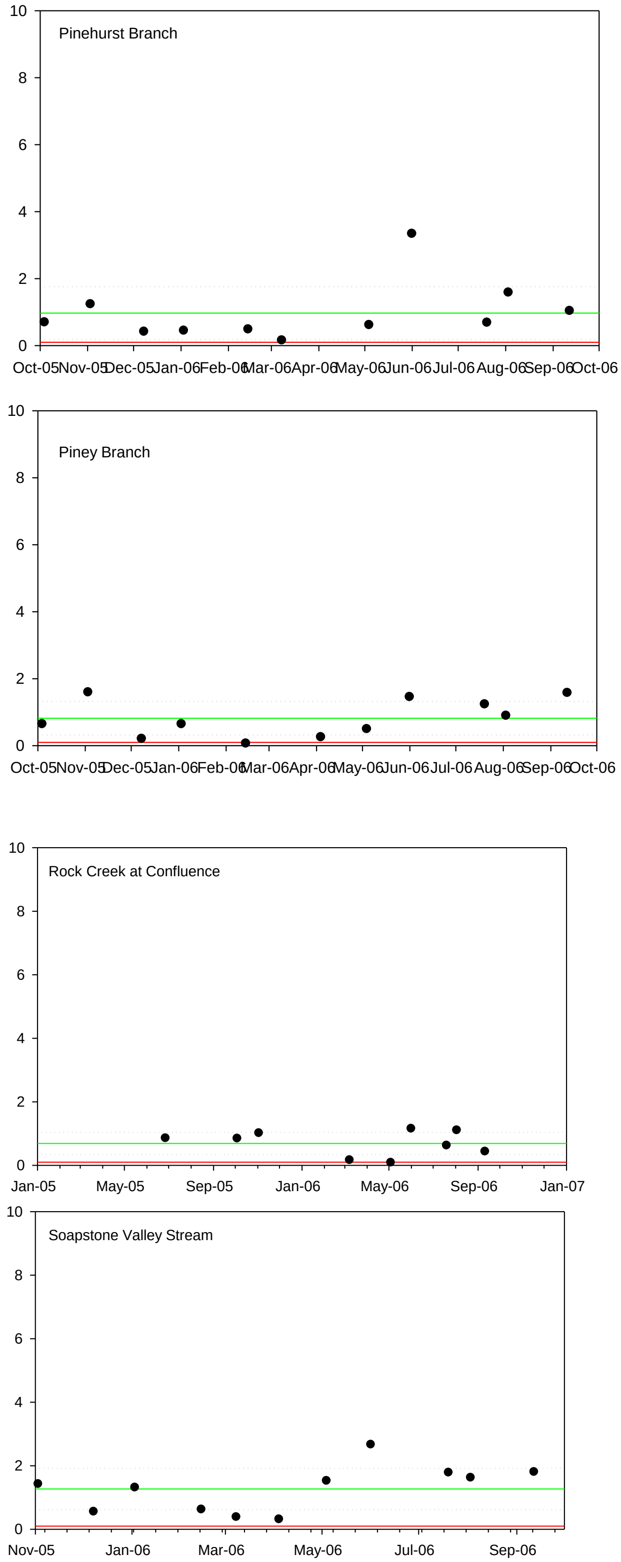

Figure 43: Total Phosphorus in Rock Creek, Soapstone Valley Stream, Pinehurst Branch, and Piney Branch 2005-2006.

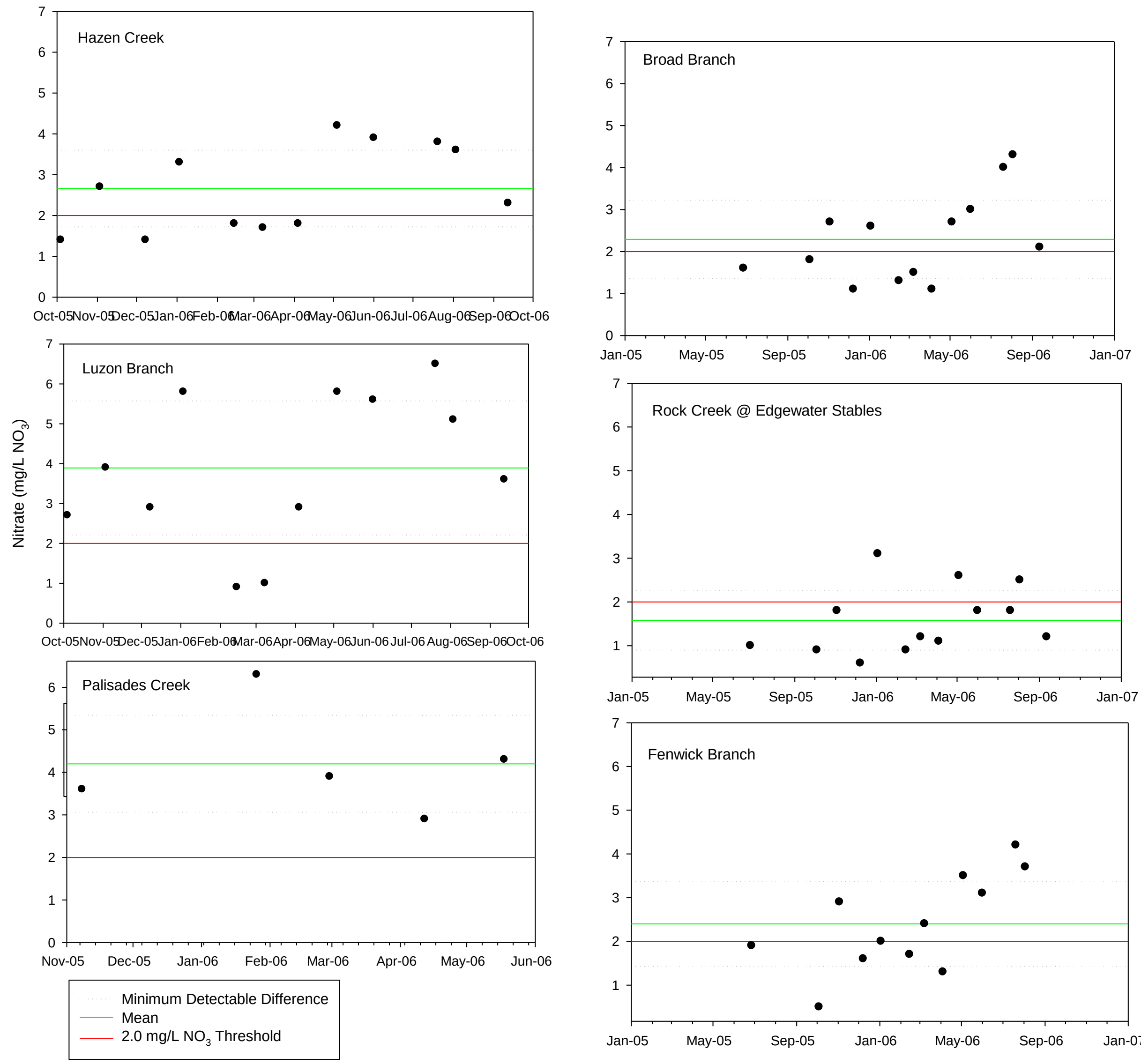

Figure 44: Nitrate in Hazen Creek, Luzon Branch, Palisades Branch, Broad Branch, Rock Creek, and Fenwick Branch 2005-2006

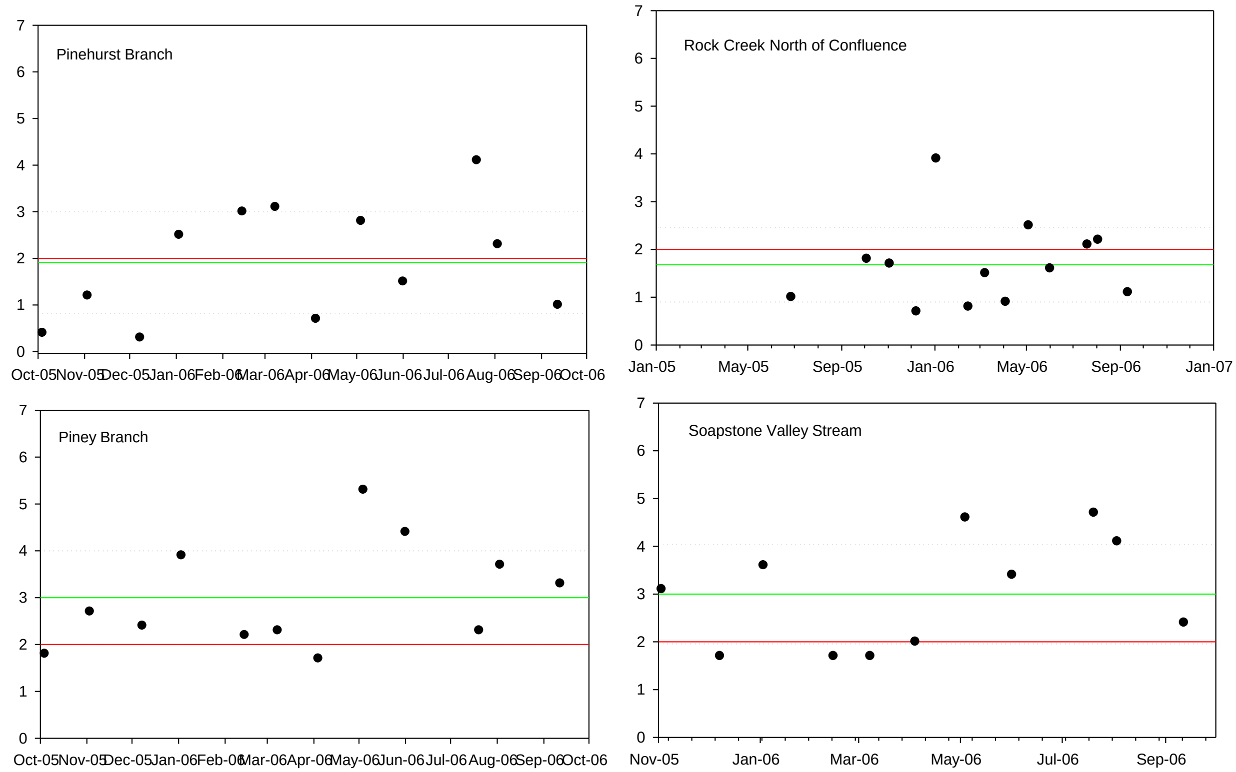

Figure 45: Nitrate in Rock Creek, Soapstone Valley Stream, Pinehurst Branch, and Piney Branch 2005-2006.

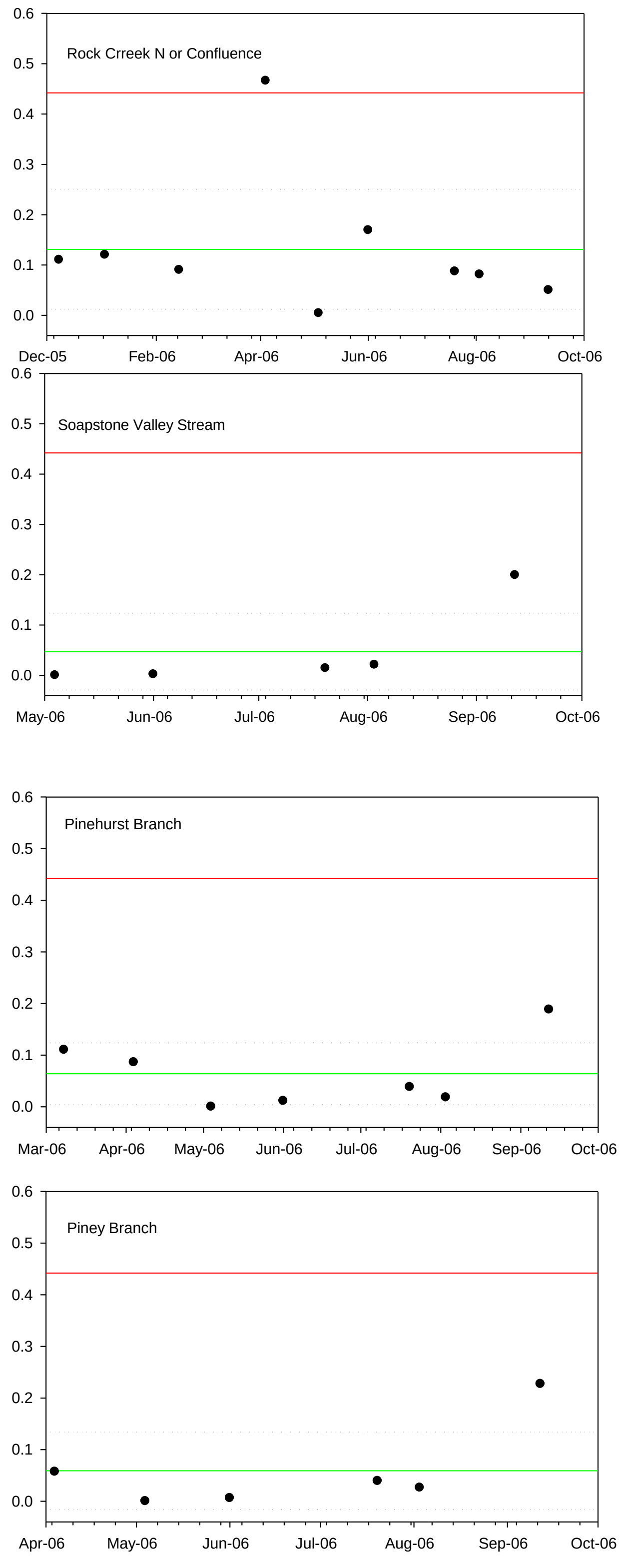

Figure 46: Ammonia in Rock Creek, Soapstone Valley Stream, Pinehurst Branch, and Piney Branch 2005-2006.

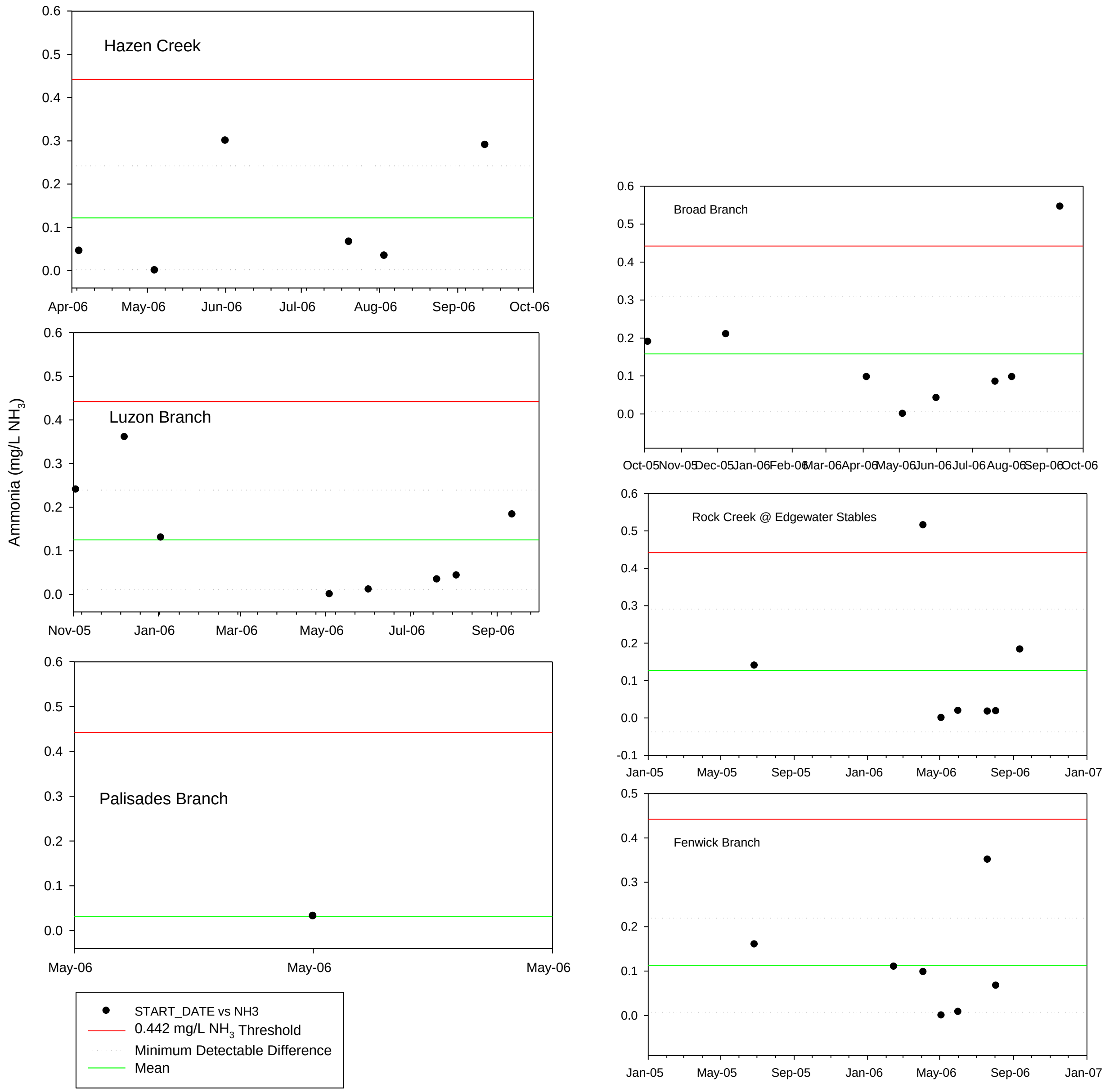

Figure 47: Ammonia in Hazen Creek, Luzon Branch, Palisades Branch, Broad Branch, Rock Creek, and Fenwick Branch 2005-2006.

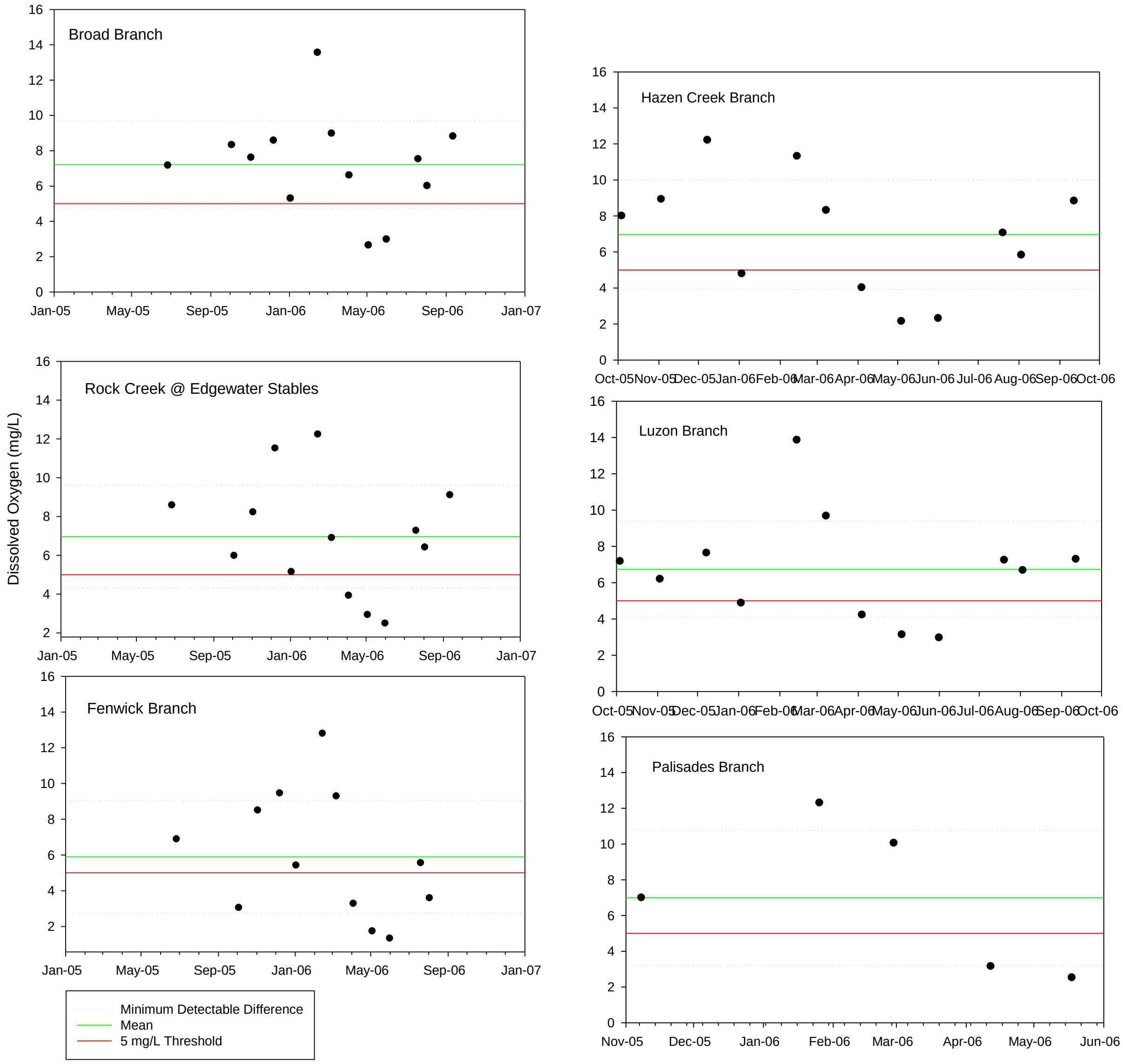

Figure 48: Dissolved Oxygen in Hazen Creek, Luzon Branch, Palisades Branch, Broad Branch, Rock Creek, and Fenwick Branch 2005-2006

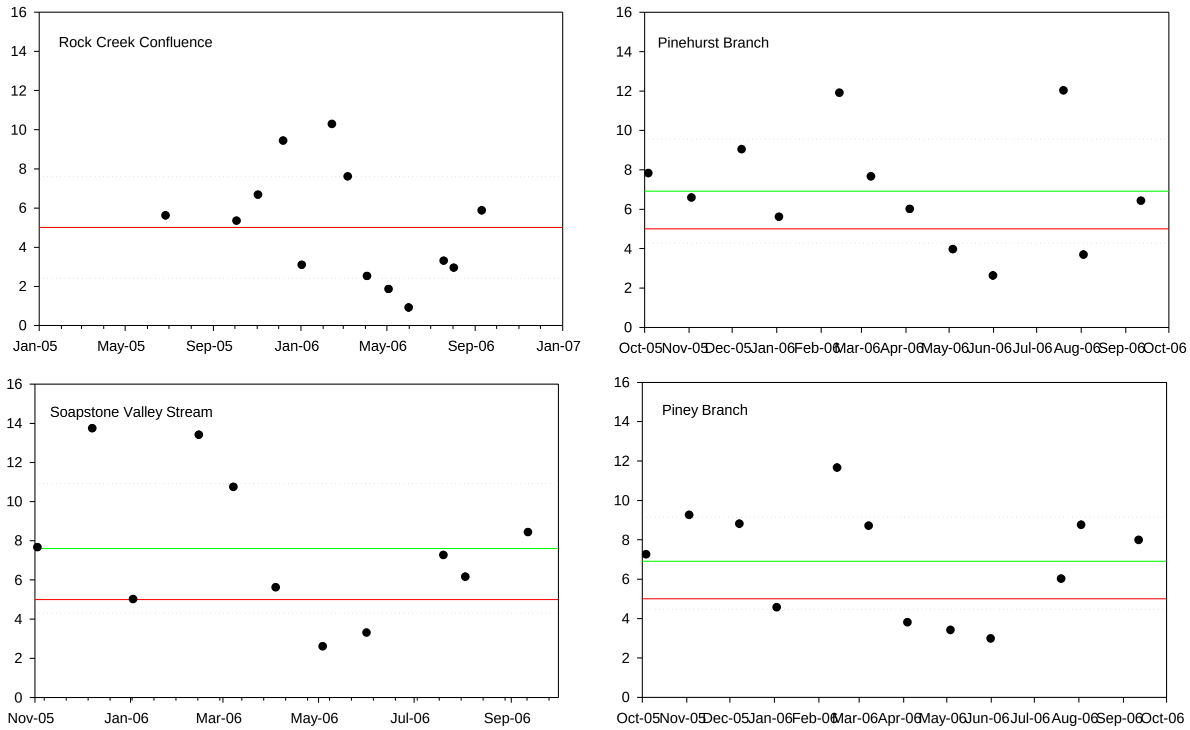

Figure 49: Dissolved Oxygen in Rock Creek, Soapstone Valley Stream, Pinehurst Branch, and Piney Branch 2005-2006.

National Capital Parks – East (NACE)
NACE encompasses approximately 8,000 acres of park lands, is located within the Coastal Plain Physiographic Province in Prince George's County, Maryland and the District of Columbia (Washington, DC). The park is located within the Middle Potomac-Anacostia-Occoquan watershed (USGS hydrologic unit 02070010) and includes parts of the Anacostia River, Oxon Run, Henson Creek, Accokeek Creek, Piscataway Creek and their tributaries. The park is urban and fragmented surrounded by and containing a variety of land use including agricultural, historical, and military use.

NCRN monitors five sites: Still Creek a tributary of the Anacostia within Greenbelt Park near the intersection of Kenilworth Avenue and Good Luck Road, approximately 500 meters upstream of the intersection; Fort DuPont Park Stream also a tributary of the Anacostia; Henson Creek is just off of the Suitland Parkway in the Town of Morningside; Oxon Run within Oxon Cove Park; an unnamed tributary of Accokeek Creek within Piscataway Park along the Forest Trail just downstream of the first stream crossing.

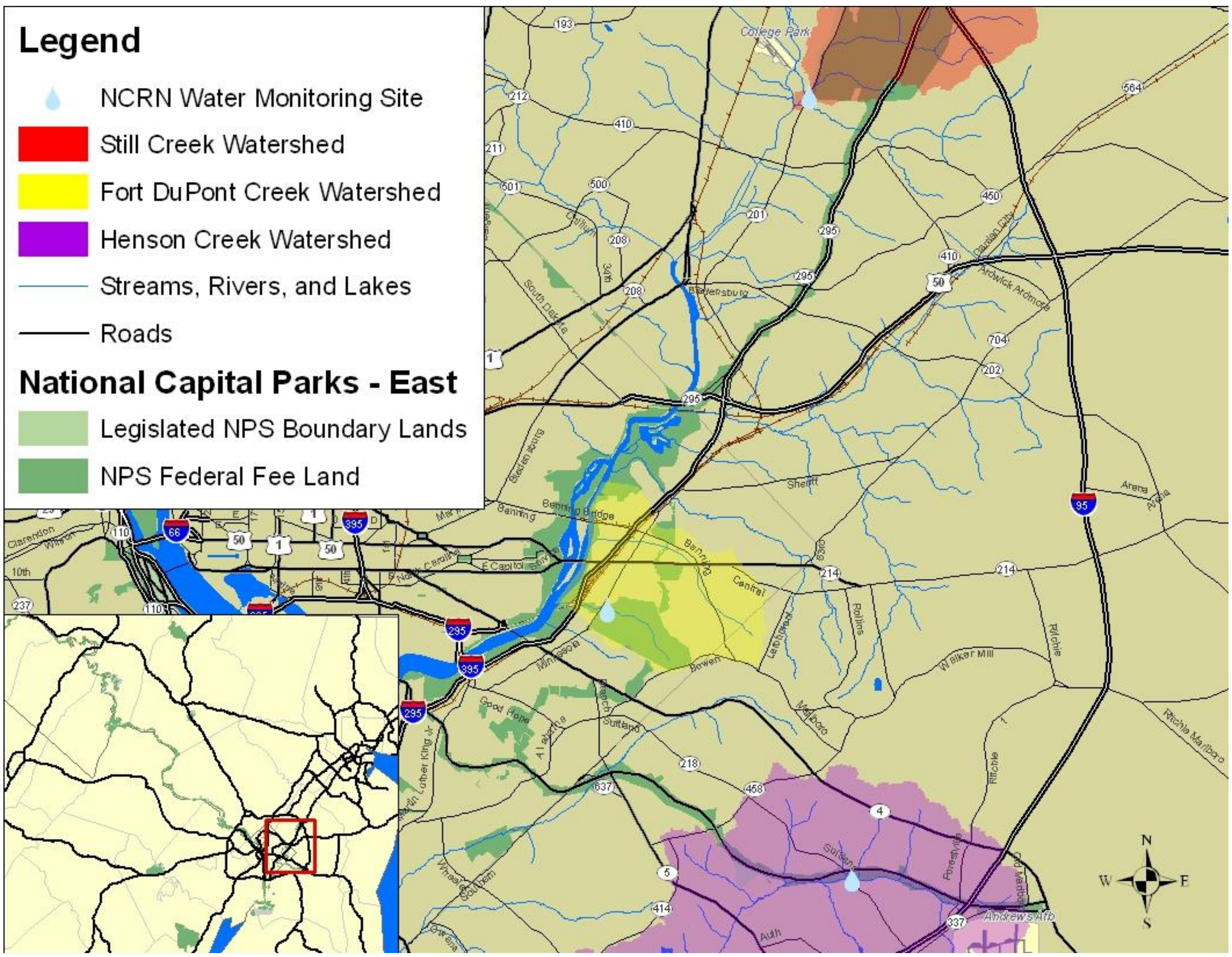

Figure 50: Relationship of the Stream monitoring sites in Still Creek and an unnamed stream in Ft. Dupont, and Henson Creek to their watersheds and the park subunit boundaries

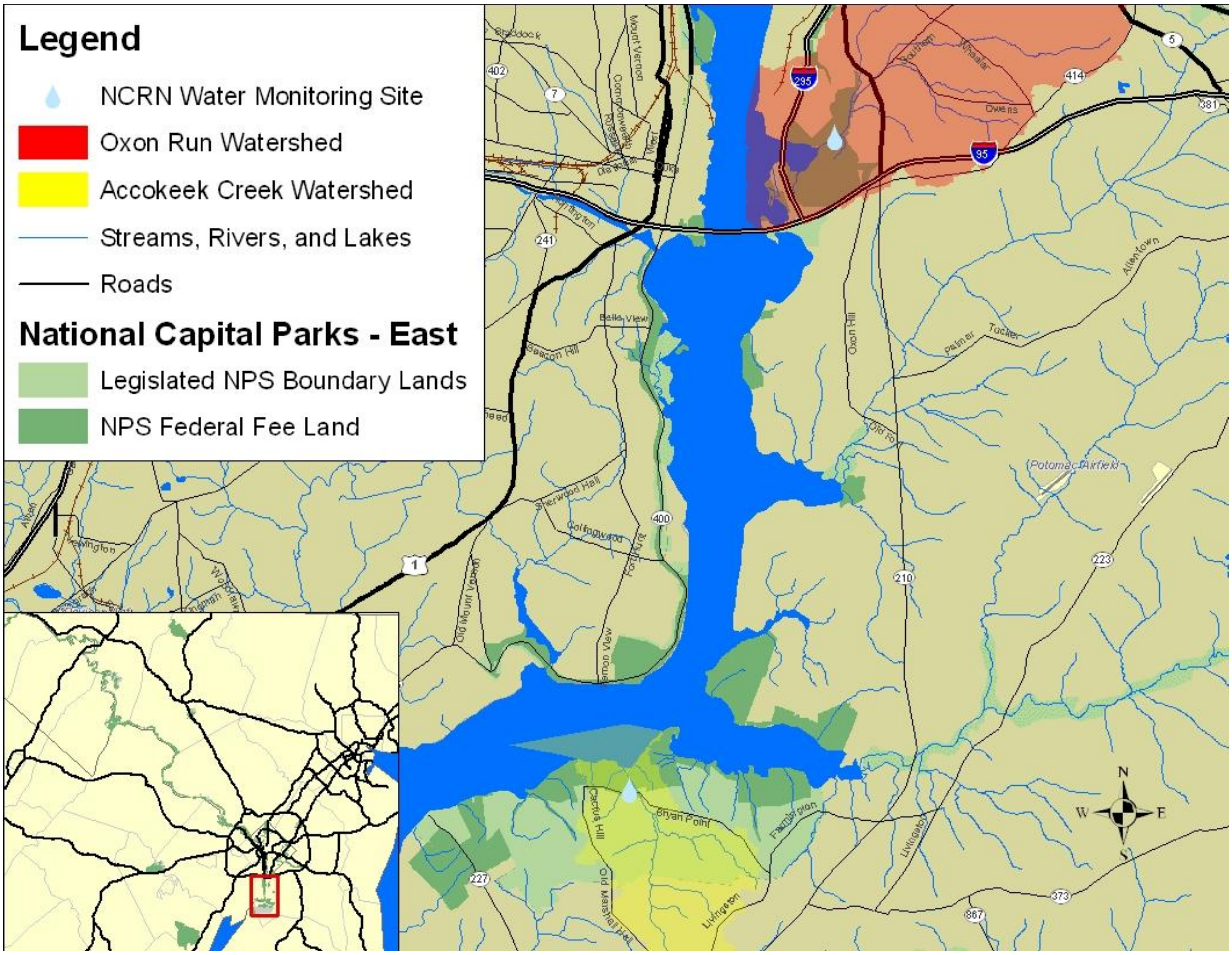

Figure 51: Relationship of the Stream monitoring sites in Oxon Run and an unnamed tributary of Accokeek Creek to their watersheds and the park subunit boundaries

Table 18: Date range, number of site visits, and data range for the information covered in this report.

Characteristic	Units	Period of Record	Count	Min.	Max.
Accokeek Creek					
ANC	µeq/L	11/29/2005 - 7/31/2006	7	1000	1702
DO (mg/L)	mg/l	11/29/2005 - 7/31/2006	7	2.51	9.57
Nitrate	mg/l	11/29/2005 - 7/31/2006	7	0.3	1.2
Nitrogen, Ammonia	mg/l	11/29/2005 - 7/31/2006	7	0	0.09
pH	None	11/29/2005 - 7/31/2006	7	6.72	8.21
Phosphorus	mg/l	11/29/2005 - 7/31/2006	7	0.27	1.69
Specific conductance	µS/cm	11/29/2005 - 7/31/2006	7	178	259
Fort Dupont Stream					
ANC	µeq/L	3/6/2006 - 7/31/2006	6	344	776
DO (mg/L)	mg/l	3/6/2006 - 7/31/2006	6	2.55	8.34
Nitrate	mg/l	3/6/2006 - 7/31/2006	6	0.2	0.7
Nitrogen, Ammonia	mg/l	3/6/2006 - 7/31/2006	6	0.13	0.24
pH	None	3/6/2006 - 7/31/2006	6	6.67	7.18
Phosphorus	mg/l	3/6/2006 - 7/31/2006	6	0.09	0.76
Specific conductance	µS/cm	3/6/2006 - 7/31/2006	6	244	312
Henson Creek @ Suitland Road					
ANC	µeq/L	3/6/2006 - 8/24/2006	7	418	852
DO (mg/L)	mg/l	3/6/2006 - 8/24/2006	7	2.6	9.64
Nitrate	mg/l	3/6/2006 - 8/24/2006	7	0.6	1.3
Nitrogen, Ammonia	mg/l	3/6/2006 - 8/24/2006	7	-0	0.16
pH	None	3/6/2006 - 8/24/2006	7	6.35	8.44
Phosphorus	mg/l	3/6/2006 - 8/24/2006	7	0.3	1.83
Specific conductance	µS/cm	3/6/2006 - 8/24/2006	7	312	479
Oxon Run					
ANC	µeq/L	11/29/2005 - 8/24/2006	8	576	1588
DO (mg/L)	mg/l	11/29/2005 - 8/24/2006	8	2.9	12.7
Nitrate	mg/l	11/29/2005 - 8/24/2006	8	0.4	0.9
Nitrogen, Ammonia	mg/l	11/29/2005 - 8/24/2006	8	0.08	0.5
pH	None	11/29/2005 - 8/24/2006	8	6.91	9.38
Phosphorus	mg/l	11/29/2005 - 8/24/2006	8	0.05	1.57
Specific conductance	µS/cm	11/29/2005 - 8/24/2006	8	329	496
Still Creek, Greenbelt Park					
ANC	µeq/L	3/6/2006 - 8/24/2006	7	438	912
DO (mg/L)	mg/l	3/6/2006 - 8/24/2006	7	2.27	8.57
Nitrate	mg/l	3/6/2006 - 8/24/2006	7	0.2	0.7
Nitrogen, Ammonia	mg/l	3/6/2006 - 8/24/2006	7	0	0.1
pH	None	3/6/2006 - 8/24/2006	7	6.76	7.43
Phosphorus	mg/l	3/6/2006 - 8/24/2006	7	0.3	1.28
Specific conductance	µS/cm	3/6/2006 - 8/24/2006	7	195	428

Table 19: Condition assessment and significance for site visits to National Capital Parks - East Streams 2005 – 2006.

Stream	ANC	DO	NH_3	NO_3	pH	PO_4	SC
Accokeek Creek	0	29	0	0	0	100	0
Fort Dupont Stream	0	17	0	0	0	60	0
Henson Creek	0	14	0	0	0	100	43
Oxon Run	0	25	12	0	0	86	75
Still Creek	0	24	0	0	0	100	29

Most measures within NACE were surprisingly good and within thresholds, which is especially interesting considering the highly urban nature of surrounding landscapes. At all sites, drops in dissolved oxygen are observable during the spring and summer months. This is likely due to increased biological oxygen demand and during the decomposition stage that follows algal blooms. Average phosphorus levels exceeded thresholds at all sites. While this is observed at all parks, specific sources need identification.

A spike in ammonia occurred during December 2005 at Oxon Run. This may be due to sewer leaks upstream, exact location needs to be determined and addressed.

The mean specific conductance for Oxon Run exceeds the threshold; while at Henson Creek, the mean is dangerously close to exceed this level of ecological stress. Like ROCR, there seems to be impacts from sewer overflows in several of the streams. The interaction of the sanitary sewer system and the streams needs to be investigated.

These measures constitute a snap shot of stream conditions in time and space, and are not representative of quality over a 24 hour period. All of these measures are influenced to a certain degree by biological activity which follows diurnal and seasonal patterns of temperature and sunlight.

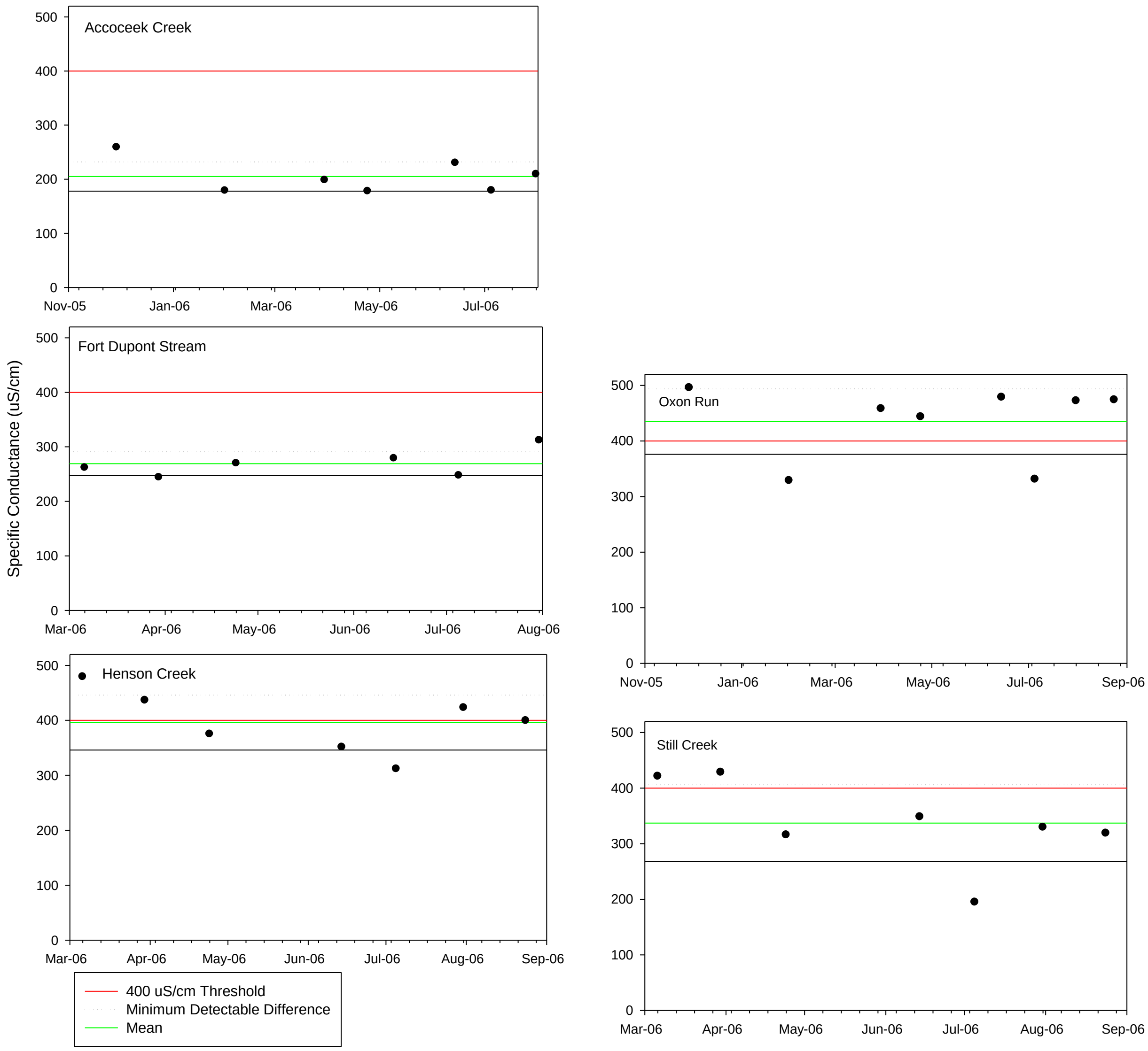

Figure 52: Specific Conductance in National Capital Parks - East Streams over time.

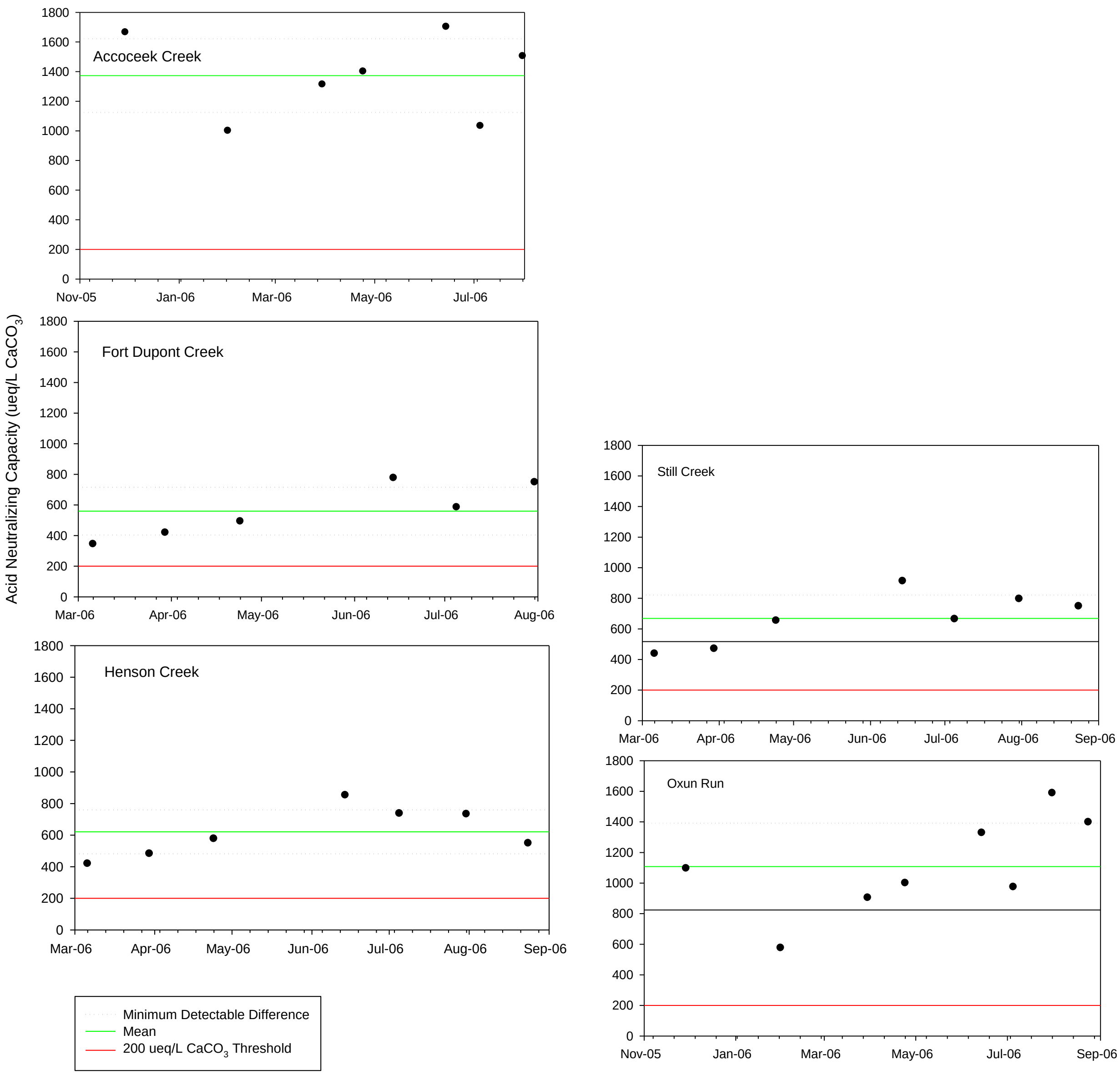

Figure 53: ANC in National Capital Parks - East Streams over time.

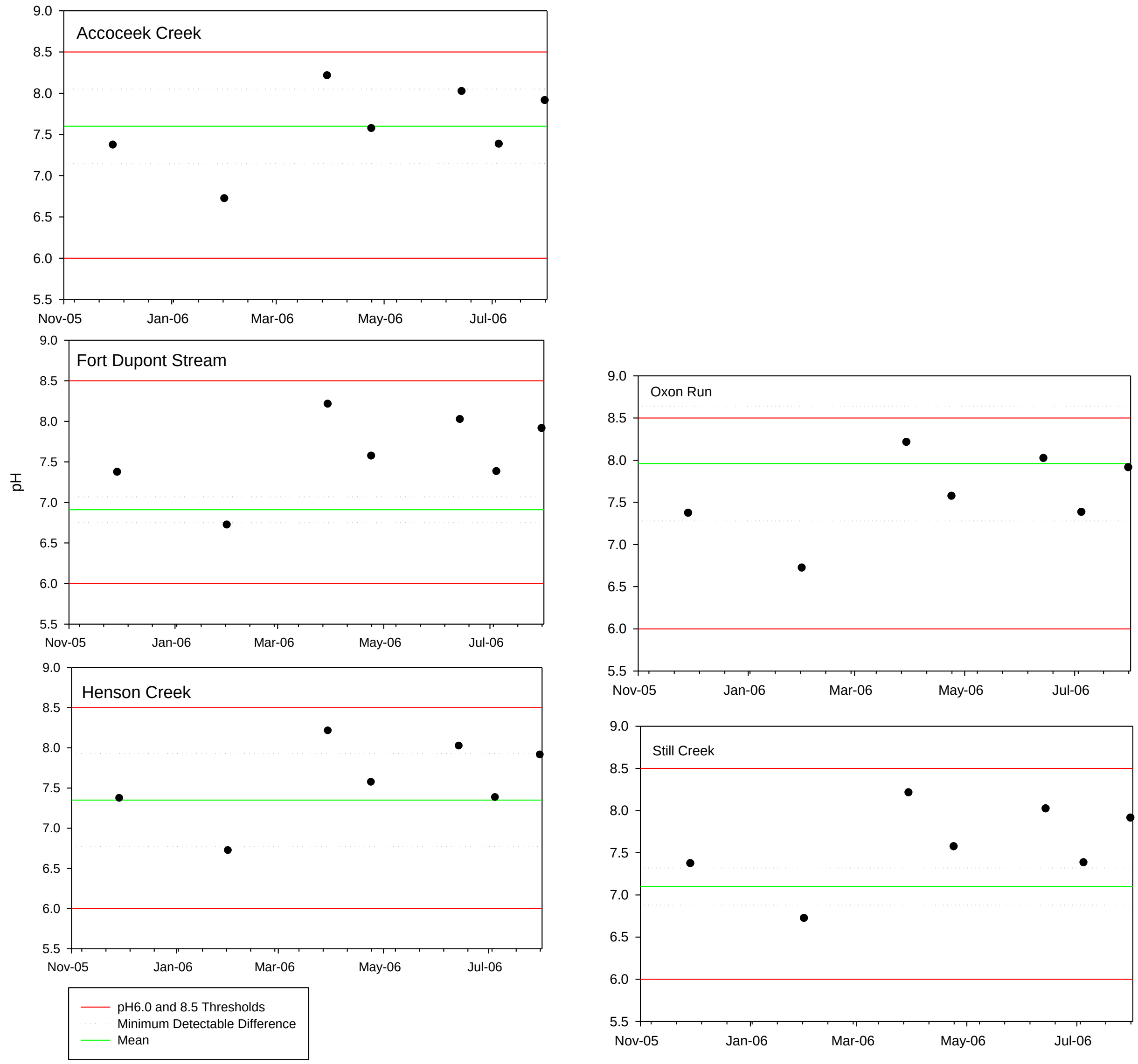

Figure 54: pH in National Capital Parks - East Streams over time.

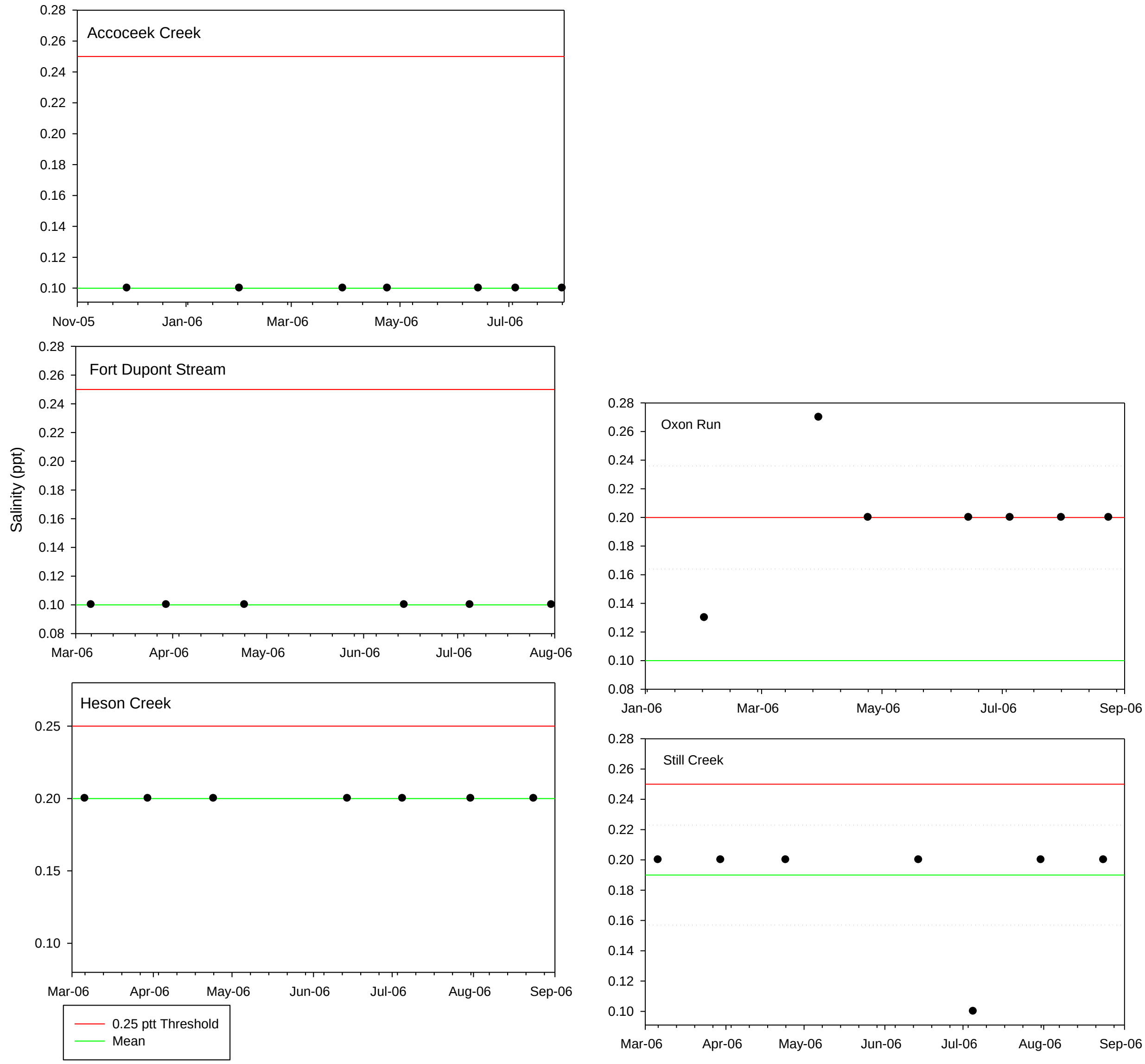

Figure 55: Salinity in National Capital Parks - East Streams over time.

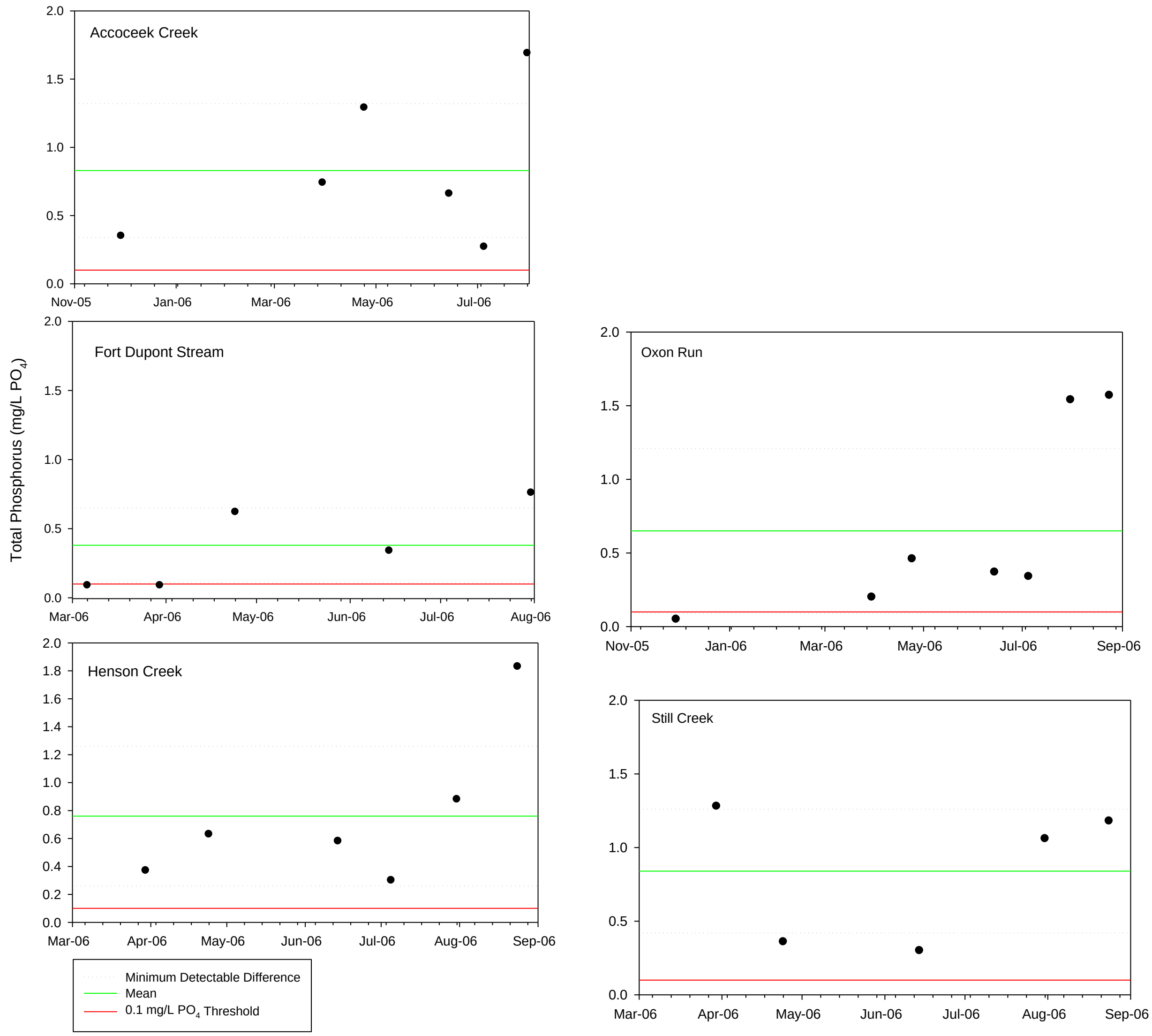

Figure 56: Total Phosphorus in National Capital Parks - East Streams over time.

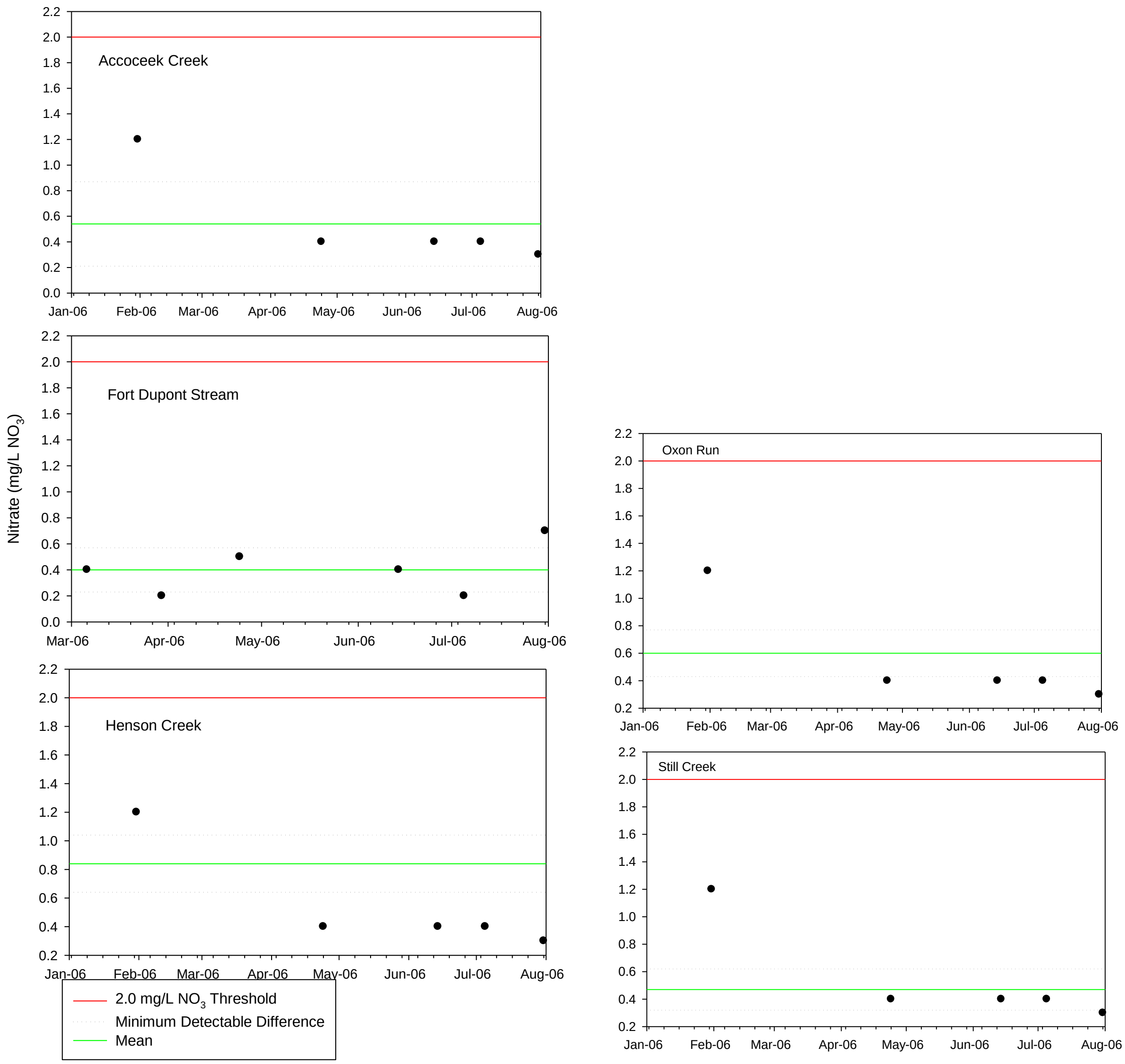

Figure 57: Nitrate in National Capital Parks - East Streams over time.

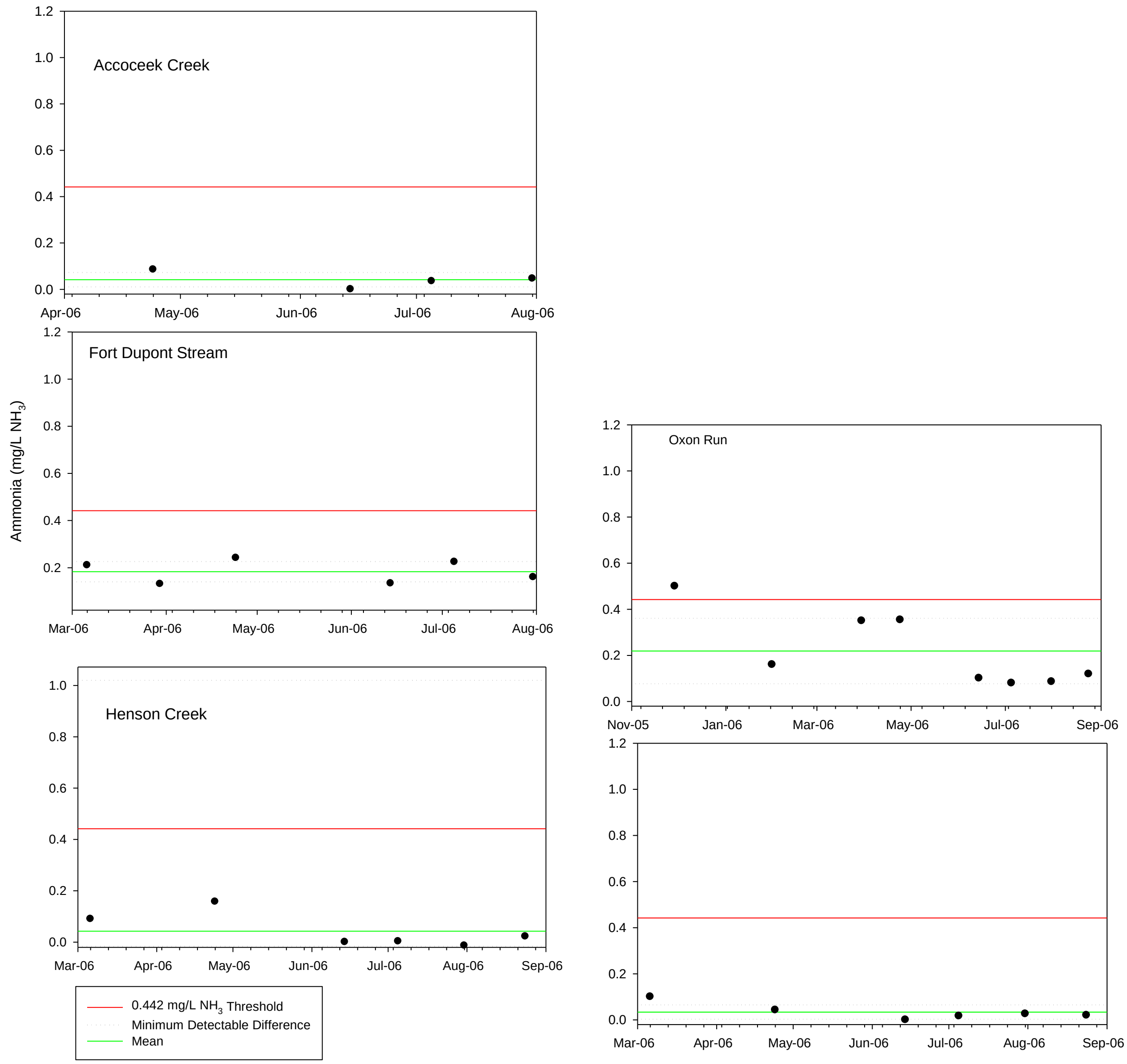

Figure 58: Ammonia in National Capital Parks - East Streams over time.

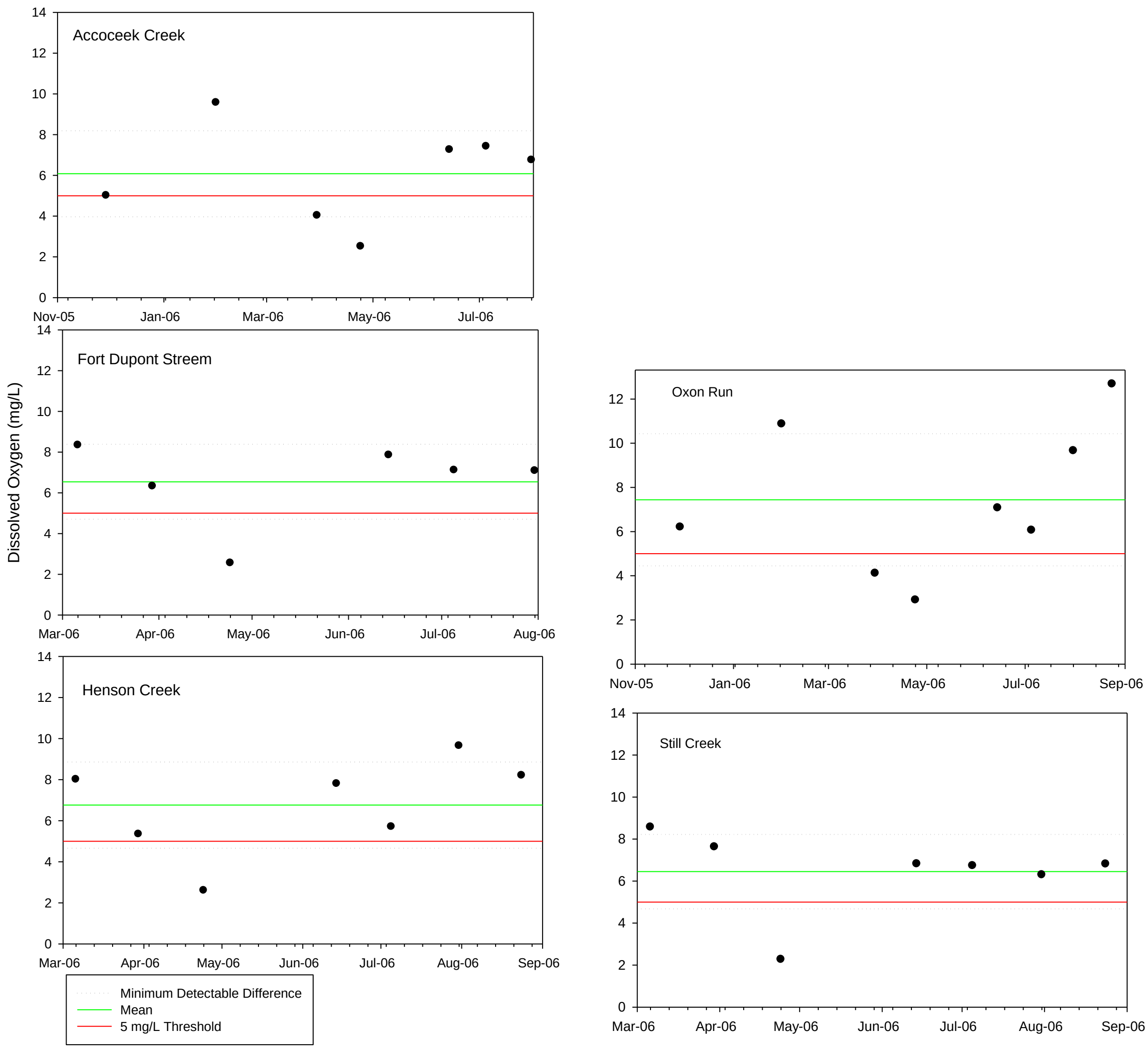

Figure 59: Dissolved Oxygen in National Capital Parks - East Streams over time.

Wolf Trap National Park for the Performing Arts (WOTR)
WOTR is a 130-acre park located within the Piedmont Physiographic Province in Fairfax County, Virginia. The park's three streams, Old Court House Branch, Wolf Trap Creek, and Wolf Trap Run, and their riparian forest are among the park's most important natural resources. Wolf Trap is characterized by rolling hills, a mild climate, and year-round rainfall. Historically, the land use of the park was agricultural farmland. Today, the park is a major concert venue, with its land use equally split between forested and developed. The surrounding lands are heavily suburbanized.

WOTR is part of the Middle Potomac-Catoctin watershed (USGS hydrologic unit 02070008 and contains parts of Wolf Trap Creek and its tributaries Wolf Trap Run and Old Courthouse Creek. Wolf Trap Creek itself drains into Difficult Run, a stream sampled at GWMP. NCRN monitors two sites; Wolf Trap Creek and Old Courthouse Creek. Both creeks drain the surrounding neighborhoods before entering the park. Stream bank erosion has occurred due to increased development around the park. The erosion may threaten the maintenance yard in the future. This has lead to sediment deposition. Runoff from the Dulles Toll Road may have detrimental effects. Streams are also impacted by fertilizer runoff from the park's management, parking lot runoff, and runoff from salt storage in the maintenance yard.

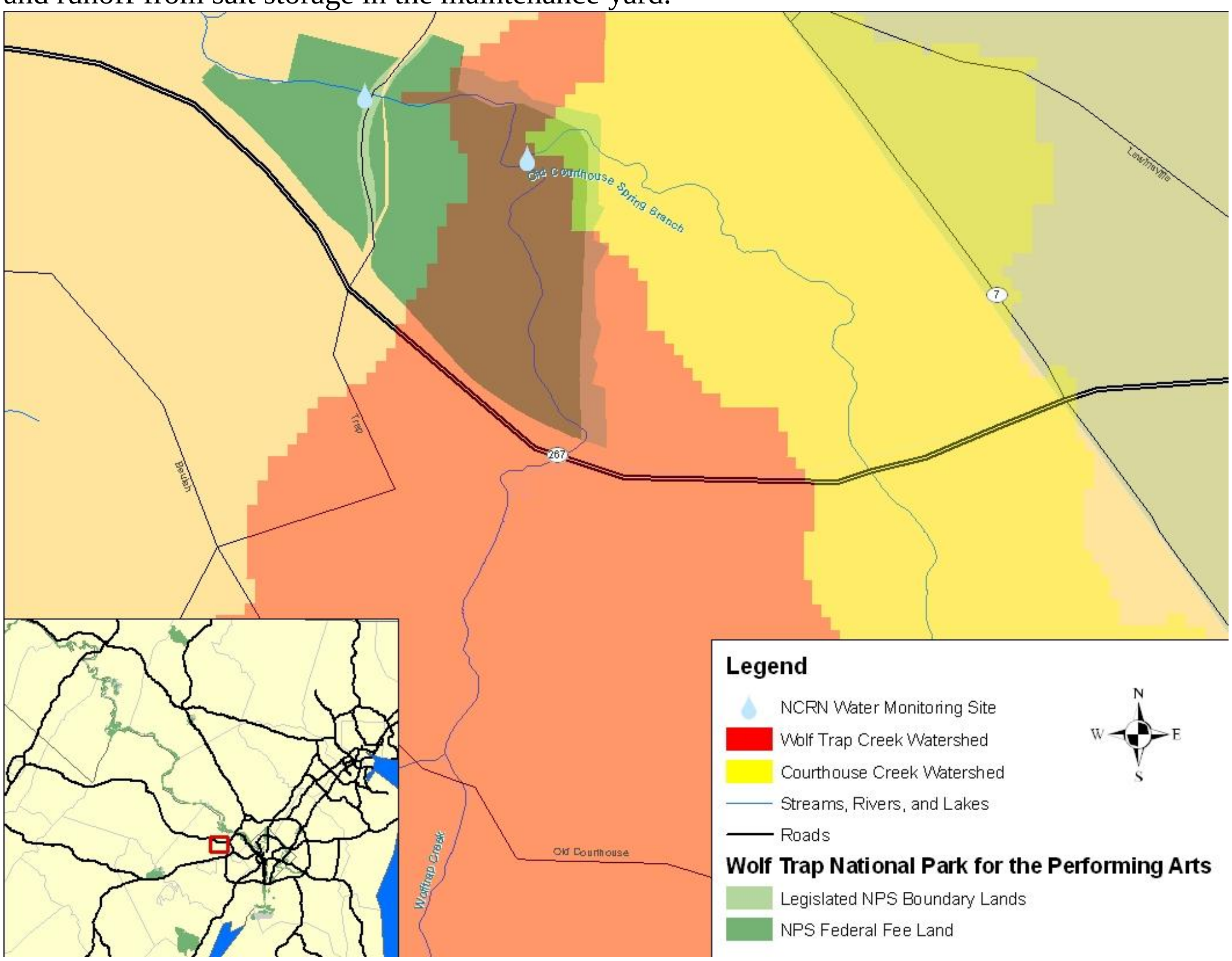

Figure 60: Relationship of the Wolf Trap Creek monitoring site to the watershed and the park boundary

Table 20: Date range, number of site visits, and data range for the information covered in this report.

Courthouse Creek					
Characteristic	**Units**	**Period of Record**	**Count**	**Min.**	**Max.**
ANC	µeq/L	5/2/2006 - 9/25/2006	5	478	920
DO (mg/L)	mg/l	5/2/2006 - 9/25/2006	5	3.58	8.17
Nitrate	mg/l	5/2/2006 - 9/25/2006	5	1.3	2.1
Nitrogen, Ammonia	mg/l	5/2/2006 - 9/25/2006	5	0.018	0.173
pH	None	5/2/2006 - 9/25/2006	5	7.24	7.7
Phosphorus	mg/l	5/2/2006 - 9/25/2006	5	0.74	10.2
Specific conductance	µS/cm	5/2/2006 - 9/25/2006	5	160.4	300.3
Wolf Trap Creek					
Characteristic	**Units**	**Period of Record**	**Count**	**Min.**	**Max.**
ANC	µeq/L	12/6/2005 - 9/25/2006	10	352	768
DO (mg/L)	mg/l	11/1/2005 - 9/25/2006	11	1.89	18.94
Nitrate	mg/l	11/1/2005 - 9/25/2006	11	0.8	1.8
Nitrogen, Ammonia	mg/l	11/1/2005 - 9/25/2006	11	0	1.44
pH	None	11/1/2005 - 9/25/2006	11	6.8	7.6
Phosphorus	mg/l	11/1/2005 - 9/25/2006	11	0.12	4.86
Specific conductance	µS/cm	11/1/2005 - 9/25/2006	11	153.7	1089

Table 21: Condition assessment and significance for site visits to Courthouse Creek and Wolf Trap Creek 2005 – 2006.

Stream	ANC	DO	NH_3	NO_3	pH	PO_4	SC
Courthouse Creek	0	20	0	20	0	100	0
Wolf Trap Creek	0	18	17	0	0	100	27

Spikes in specific conductance are observed on Wolf Trap Creek, with corresponding spikes in salinity. Two of the observations, during December 2005 and February 2006, are easily explained by de-icing operations in the surrounding community. However, the spike in October 2006 is not easily explained and needs further investigation to determine sources.

As expected, the mean phosphorus levels exceed the threshold. A likely source is heavy commercial fertilizer use in the surrounding community. A single spike in ammonia was observed in March 2006. No sources are known in the watershed, so additional investigation is necessary.

Drops in dissolved oxygen have been observed on Wolf Trap Creek during spring and summer months, due to an increased biological oxygen demand from growing/decomposing algae.

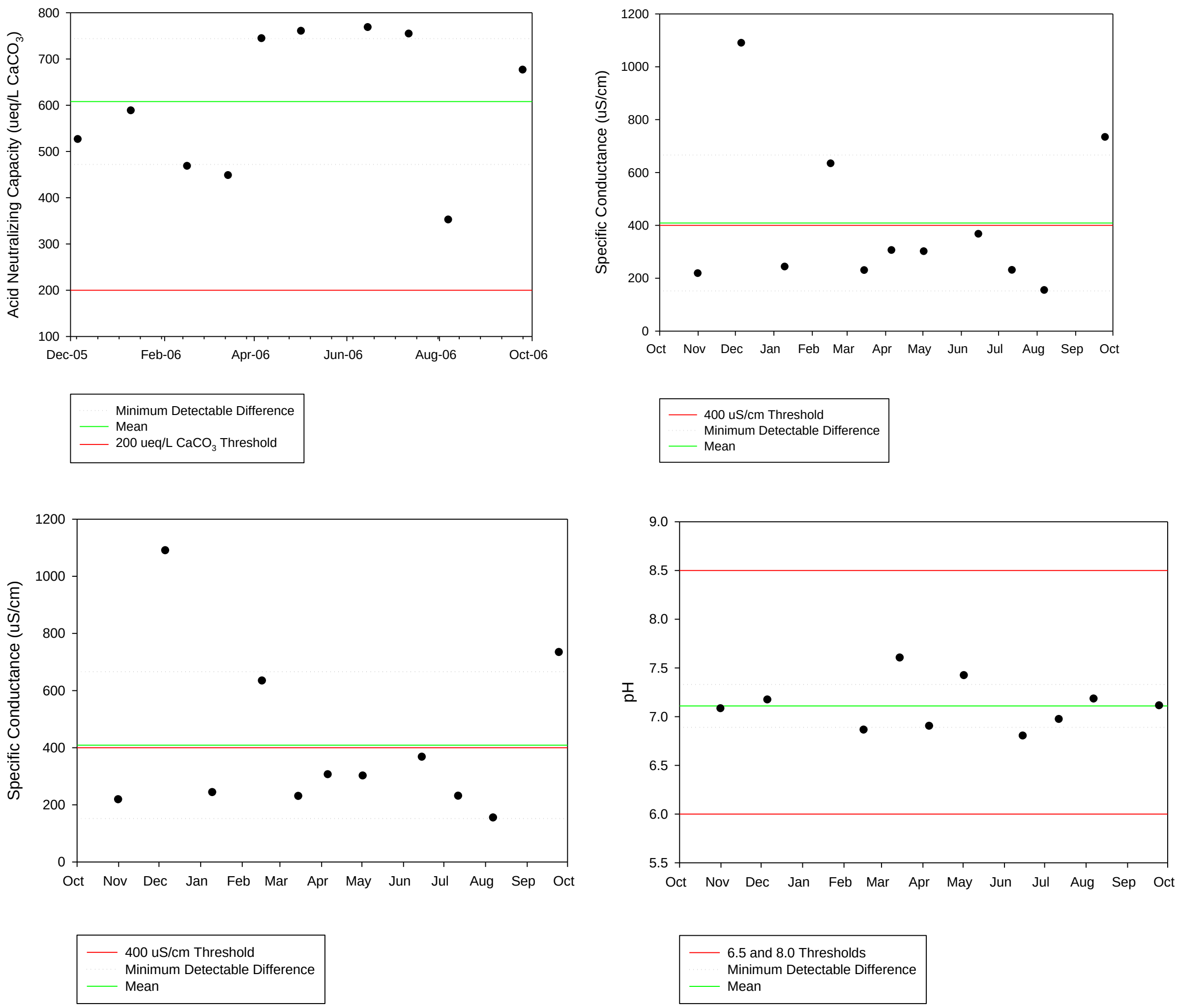

Figure 61: ANC, pH, Specific Conductance, and Salinity in Wolf Trap Creek over time.

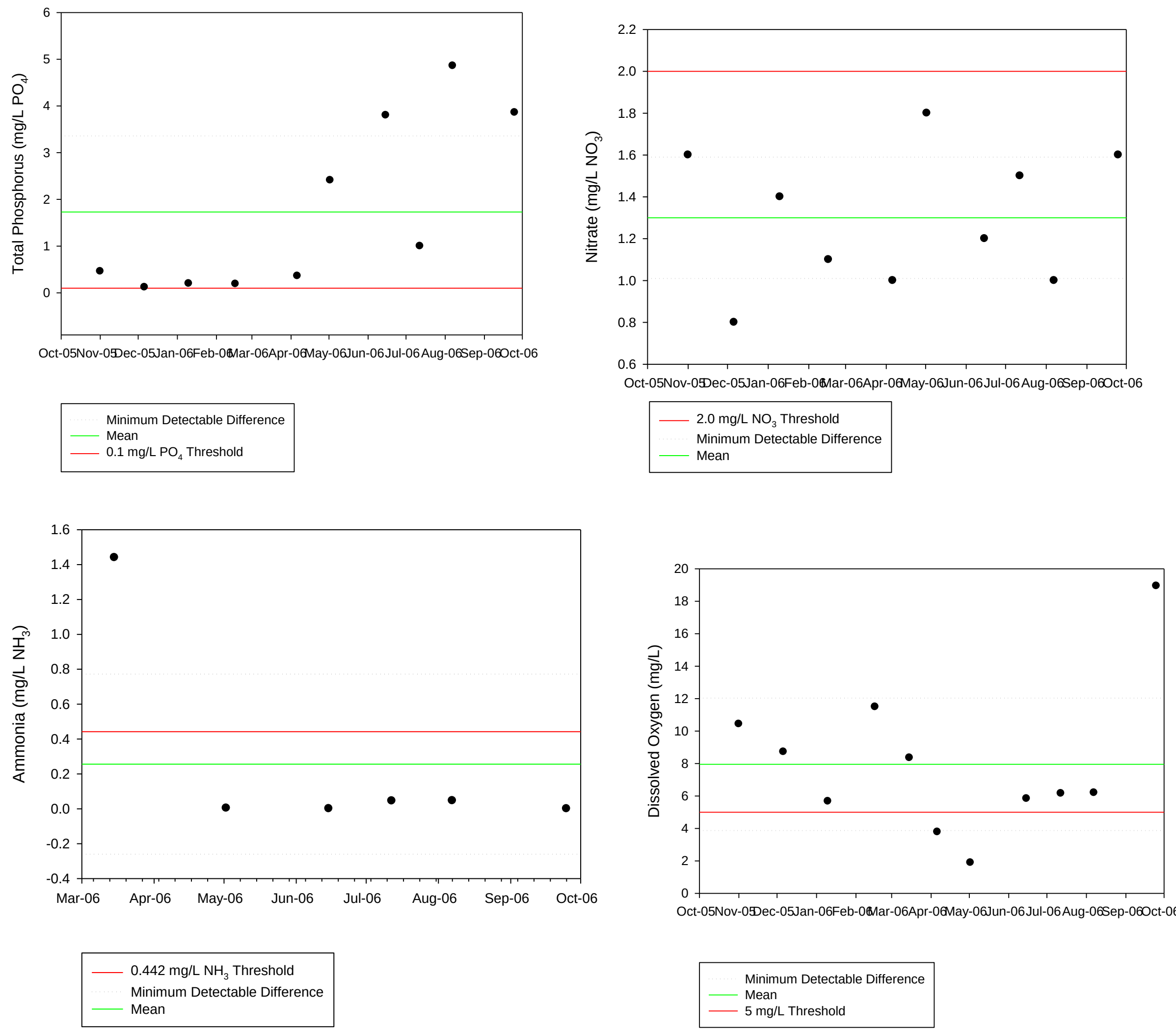

Figure 62: Nutrients and Dissolved Oxygen in Wolf Trap Creek over time

George Washington Memorial Parkway (GWMP)

GWMP comprised of approximately 7,374 acres of linear park land, within the Piedmont and Coastal Plain Physiographic Province in the City of Alexandria, and in Arlington and Fairfax Counties, Virginia and Montgomery County, Maryland. The Parkway has 40 miles of interface with the Potomac River, 12 freshwater streams, a freshwater tidal marsh, and several ponds. GWMP is part of the Middle Potomac-Catoctin watershed (USGS hydrologic unit 02070008). A number of small streams cross the park before entering the Potomac River. Highway runoff, soil runoff, agricultural runoff, construction activities, oil and chemical spills, sewer main breaks, and overflow all affect water quality along the parkway.

NCRN monitors five sites: Pimmit Run near the Chain Bridge, along the Potomac Heritage Trail approximately 600 meters upstream of its confluence with the Potomac River; Turkey Run in Turkey Run Park, along the Potomac Heritage Trail; Difficult Run approximately 500 meters downstream of the Georgetown Pike bridge crossing; Mine Run in Great Falls Park about 100 meter upstream of its confluence with the Patowmack Canal; Minnehaha Creek at the entrance to Glen Echo Park, just downstream of the MacArthur Boulevard road crossing.

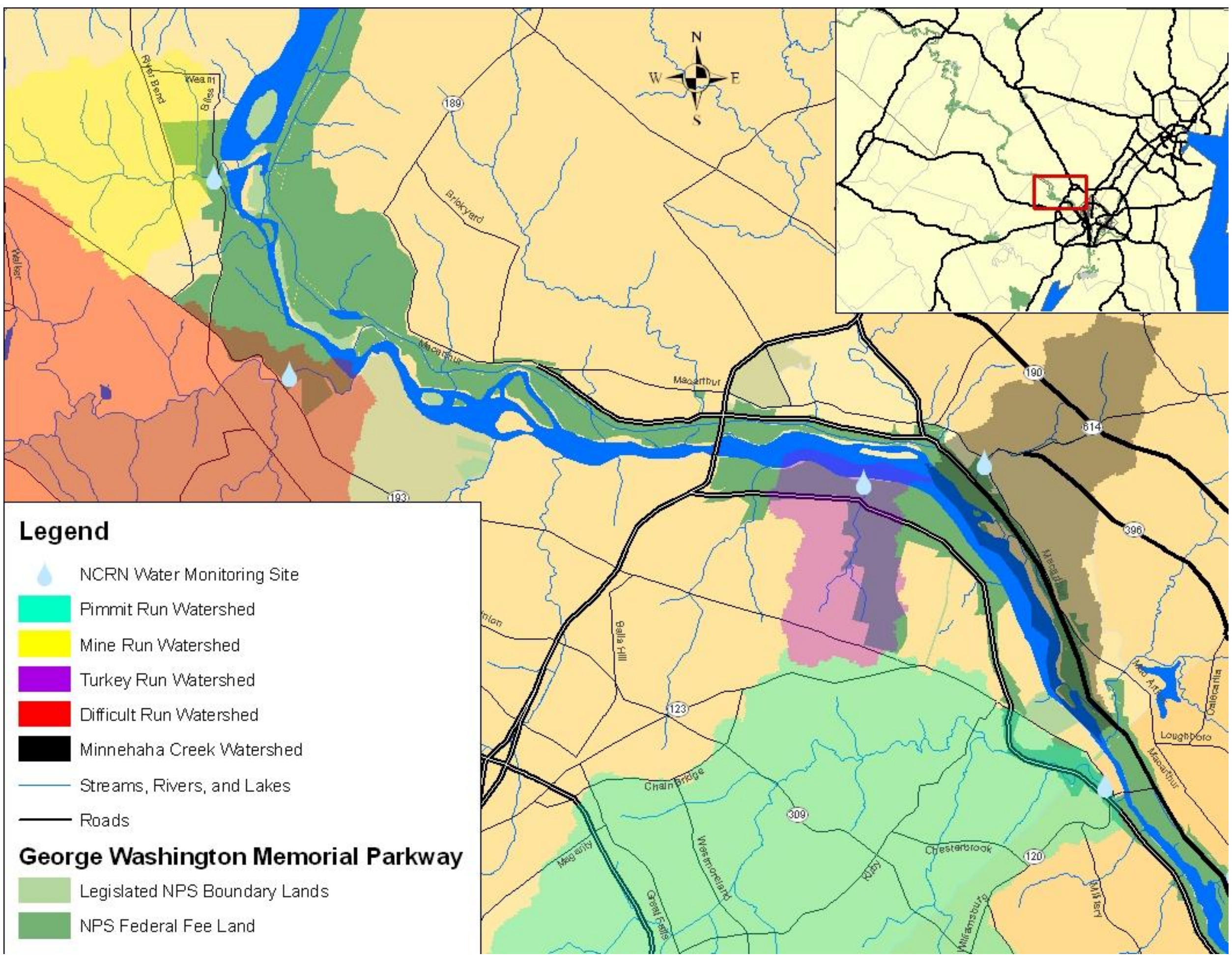

Figure 63: Relationship of the stream monitoring sites to their watersheds and the park boundary

Table 22: Date range, number of site visits, and data range for the information covered in this report.

Characteristic	Units	Period of Record	Count	Min.	Max.
Difficult Run					
ANC	µeq/L	6/14/2005 - 9/25/2006	11	350	1800
DO (mg/L)	mg/l	6/14/2005 - 9/25/2006	13	2.55	11.1
Nitrate	mg/l	6/14/2005 - 9/25/2006	13	1	2
Nitrogen, Ammonia	mg/l	6/14/2005 - 9/25/2006	13	0	0.15
pH	None	6/14/2005 - 9/25/2006	13	6.72	7.35
Phosphorus	mg/l	6/14/2005 - 9/25/2006	13	0.05	5.41
Specific conductance	µS/cm	6/14/2005 - 9/25/2006	13	178	612
Minnehaha Creek					
ANC	µeq/L	6/8/2005 - 9/25/2006	13	220	4950
DO (mg/L)	mg/l	6/8/2005 - 9/25/2006	13	1.88	10.7
Nitrate	mg/l	6/8/2005 - 9/25/2006	13	0.5	2.8
Nitrogen, Ammonia	mg/l	6/8/2005 - 9/25/2006	13	-0	0.05
pH	None	6/8/2005 - 9/25/2006	13	7.37	7.97
Phosphorus	mg/l	6/8/2005 - 9/25/2006	13	0.48	4.52
Specific conductance	µS/cm	6/8/2005 - 9/25/2006	13	206	3629
Mine Run					
ANC	µeq/L	6/14/2005 - 9/25/2006	11	178	1660
DO (mg/L)	mg/l	6/14/2005 - 9/25/2006	13	2.22	11.4
Nitrate	mg/l	6/14/2005 - 9/25/2006	13	0.8	1.5
Nitrogen, Ammonia	mg/l	6/14/2005 - 9/25/2006	13	0	0.03
pH	None	6/14/2005 - 9/25/2006	13	6.83	7.79
Phosphorus	mg/l	6/14/2005 - 9/25/2006	13	0.17	4.39
Specific conductance	µS/cm	6/14/2005 - 9/25/2006	13	128	197
Pimmit Run					
ANC	µeq/L	6/6/2005 - 9/25/2006	11	332	1064
DO (mg/L)	mg/l	6/6/2005 - 9/25/2006	13	1.99	11.5
Nitrate	mg/l	6/6/2005 - 9/25/2006	13	0.8	2.3
Nitrogen, Ammonia	mg/l	6/6/2005 - 9/25/2006	13	-0	0.1
pH	None	6/6/2005 - 9/25/2006	13	7.56	9.19
Phosphorus	mg/l	6/6/2005 - 9/25/2006	13	0.04	3.88
Specific conductance	µS/cm	6/6/2005 - 9/25/2006	13	199	862
Turkey Run					
ANC	µeq/L	6/6/2005 - 9/25/2006	12	254	3300
DO (mg/L)	mg/l	6/6/2005 - 9/25/2006	13	1.91	10.9
Nitrate	mg/l	6/6/2005 - 9/25/2006	13	0.6	1.9
Nitrogen, Ammonia	mg/l	6/6/2005 - 9/25/2006	13	-0	0.09
pH	None	6/6/2005 - 9/25/2006	13	7.6	8.85
Phosphorus	mg/l	6/6/2005 - 9/25/2006	13	0.56	5.71
Specific conductance	µS/cm	6/6/2005 - 9/25/2006	13	239	729

Table 23: Condition assessment and significance for site visits to GWMP Streams 2005 – 2006.

Stream	ANC	DO	NH_3	NO_3	pH	PO_4	SC
Difficult Run	0	25	0	0	0	82	0
Minnehaha Creek	0	31	0	38	0	100	92
Mine Run	9	31	0	9	0	83	0
Pimmit Run	0	31	0	15	18	100	15
Turkey Run	0	31	0	0	18	100	20

At Minnehaha Creek, the mean specific conductance exceeds the ecological stressor threshold, while two other streams possess means that are dangerously close to exceeding the level, with spikes that do exceed, Pimmit Run and Turkey Run. The spikes in the two streams are mainly during winter months and are likely the result of de-icing operations. However, the elevated specific conductance at Minnehaha Creek needs further investigation to determine the source.

Pimmit Run and Turkey Run also experienced spikes in pH during the spring and summer months. While this is likely due to algal activity, additional sources may need to be identified.

Phosphorus levels at all GWMP sites exceed the threshold as expected. However, numerous spikes in phosphorus levels have been observed at all sites, most notably during October 2006. Sources for this widespread elevation of phosphorus in the streams need to be identified.

Mean nitrate levels at all sites are within threshold limits, however, numerous random spikes are seen at Minnehaha Creek and Pimmit Run. Potential sources require identification.

Due to increased biological oxygen demands, drops in dissolved oxygen levels are observed during spring and summer months. This is likely due to algal growth and decomposition. Of concern is the fact the many of these drops in DO are persistent for a few months, which threatens the biological communities of the streams, especially fish.

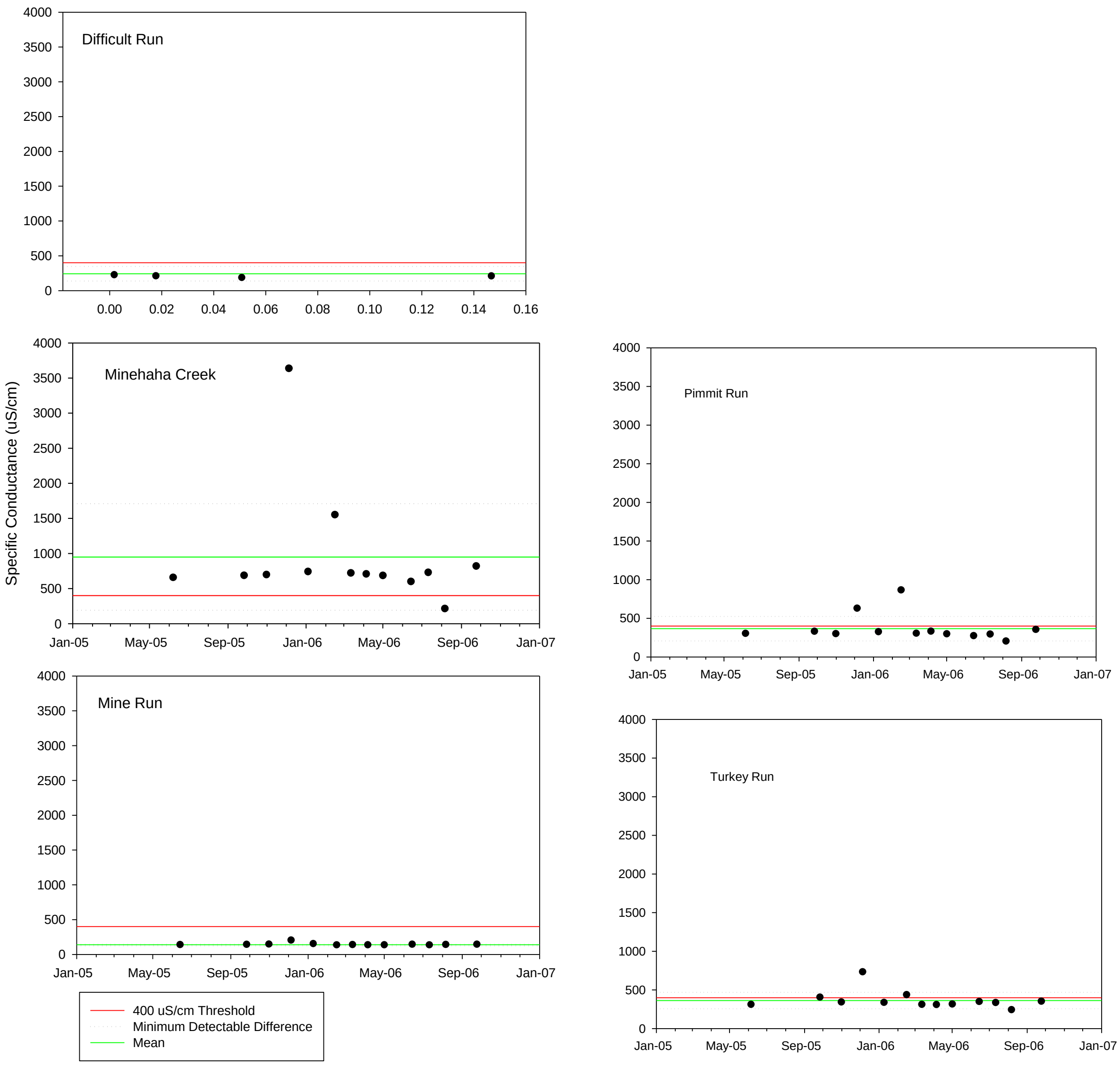

Figure 64: Specific Conductance in George Washington Memorial Parkway Streams over time.

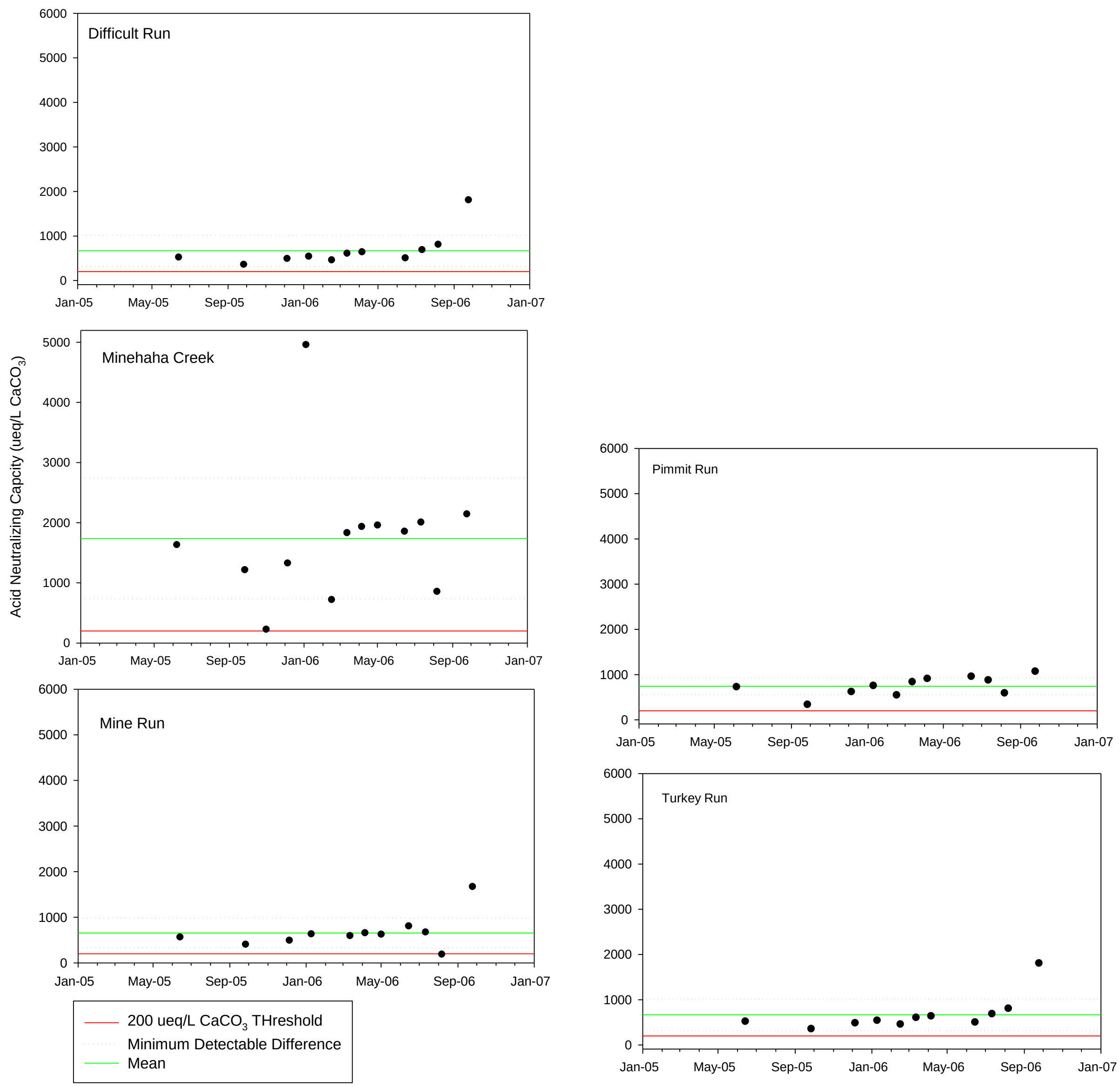

Figure 65: ANC in George Washington Memorial Parkway Streams over time.

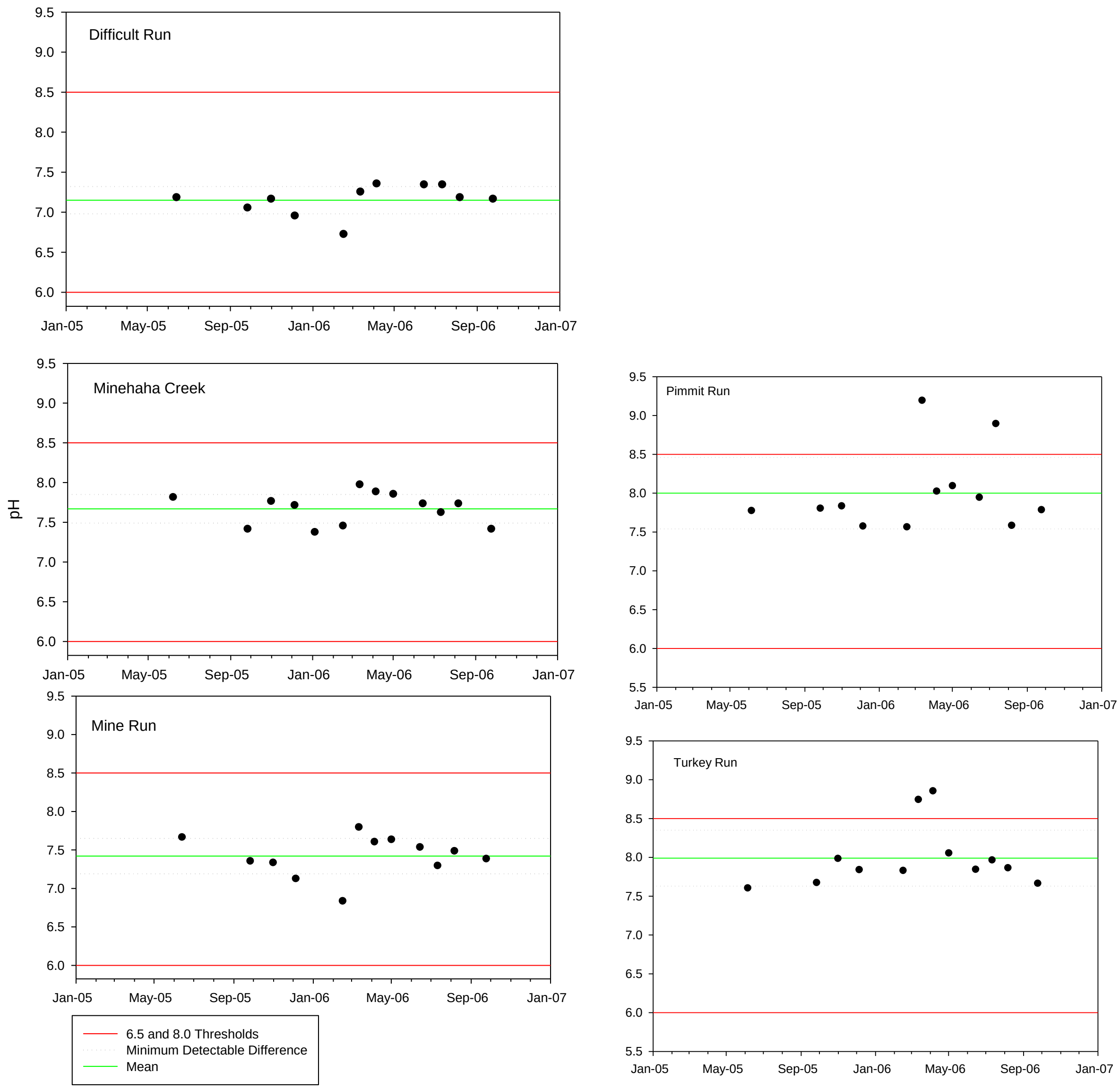

Figure 66: pH in George Washington Memorial Parkway Streams over time.

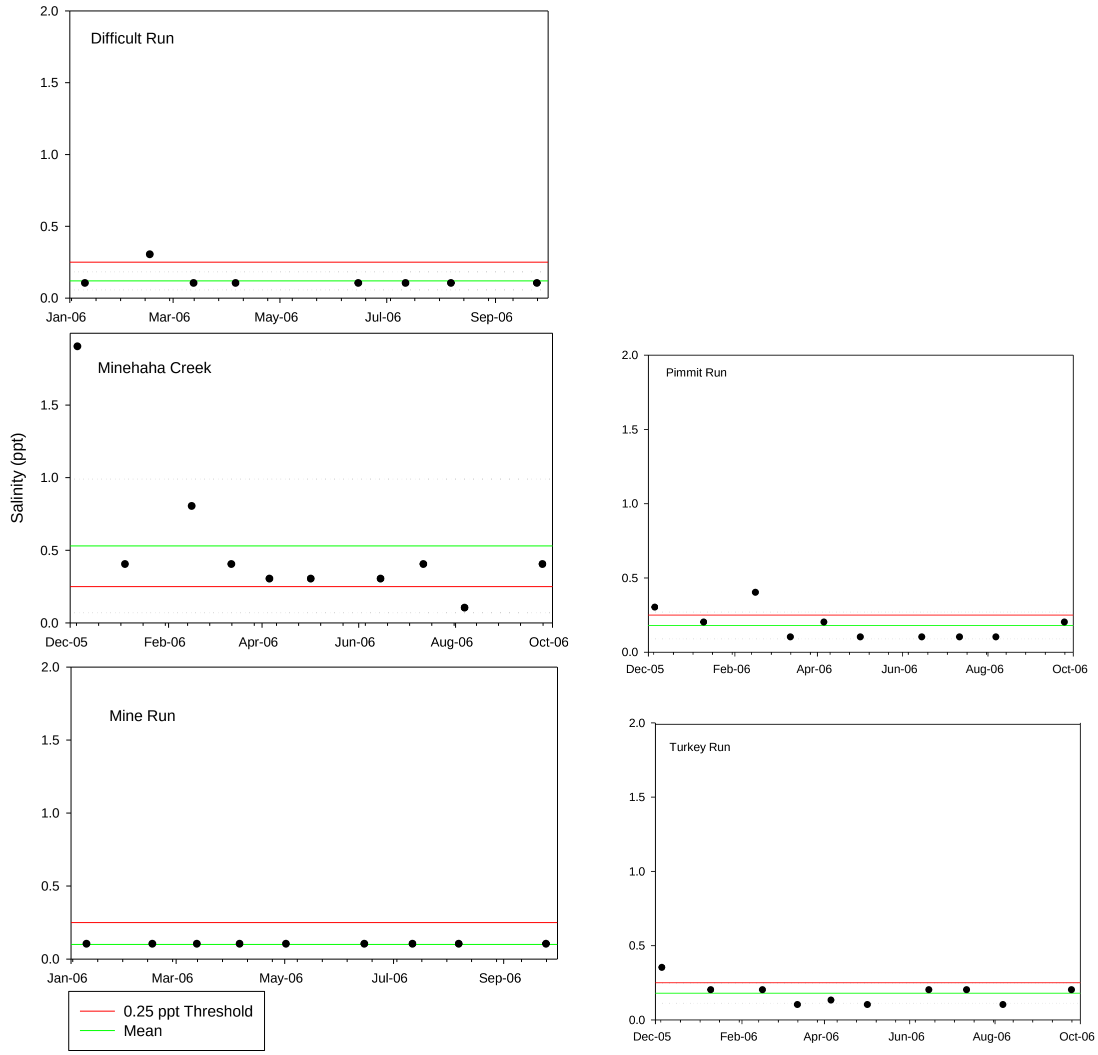

Figure 67: Salinity in George Washington Memorial Parkway Streams over time.

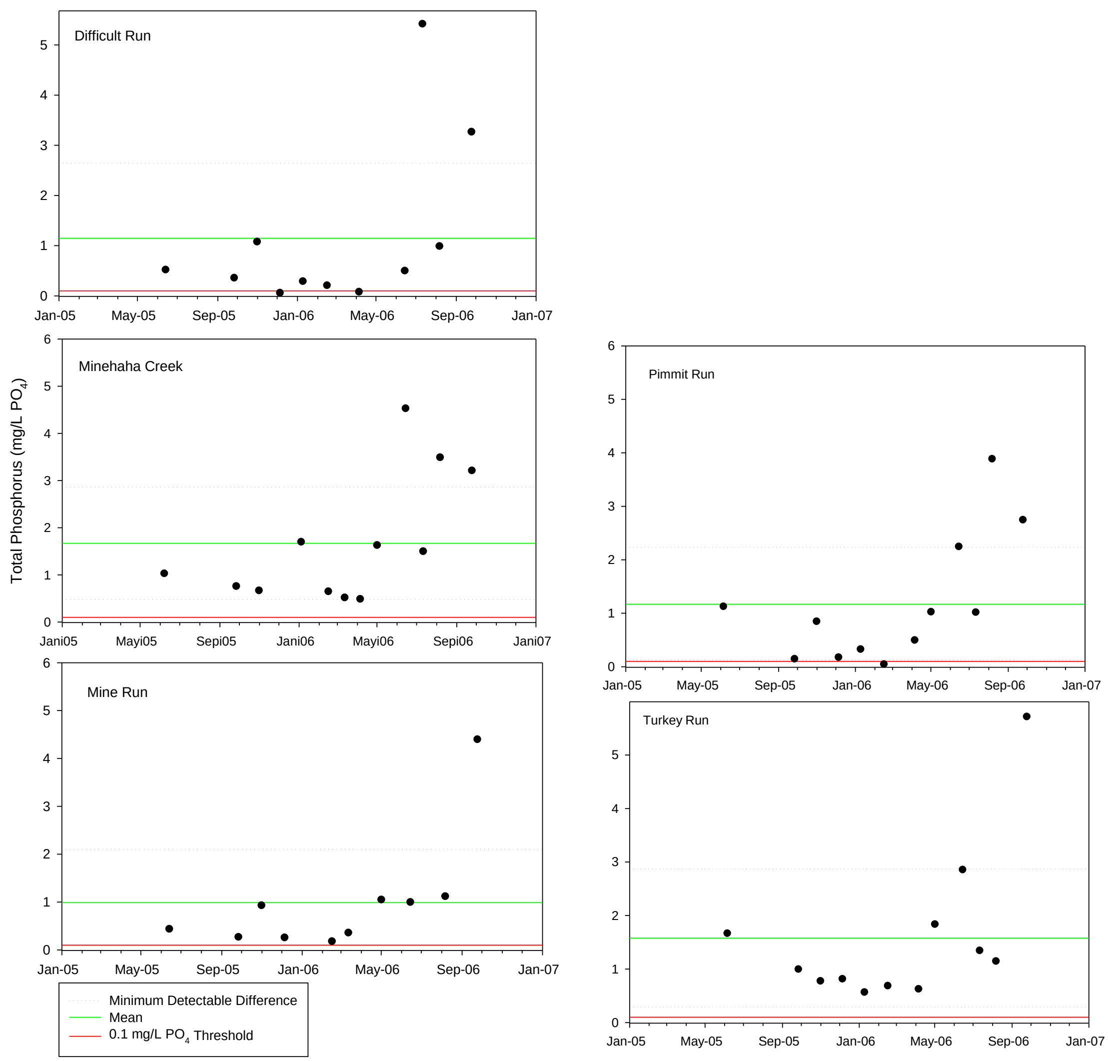

Figure 68: Total Phosphorus in George Washington Memorial Parkway Streams over time.

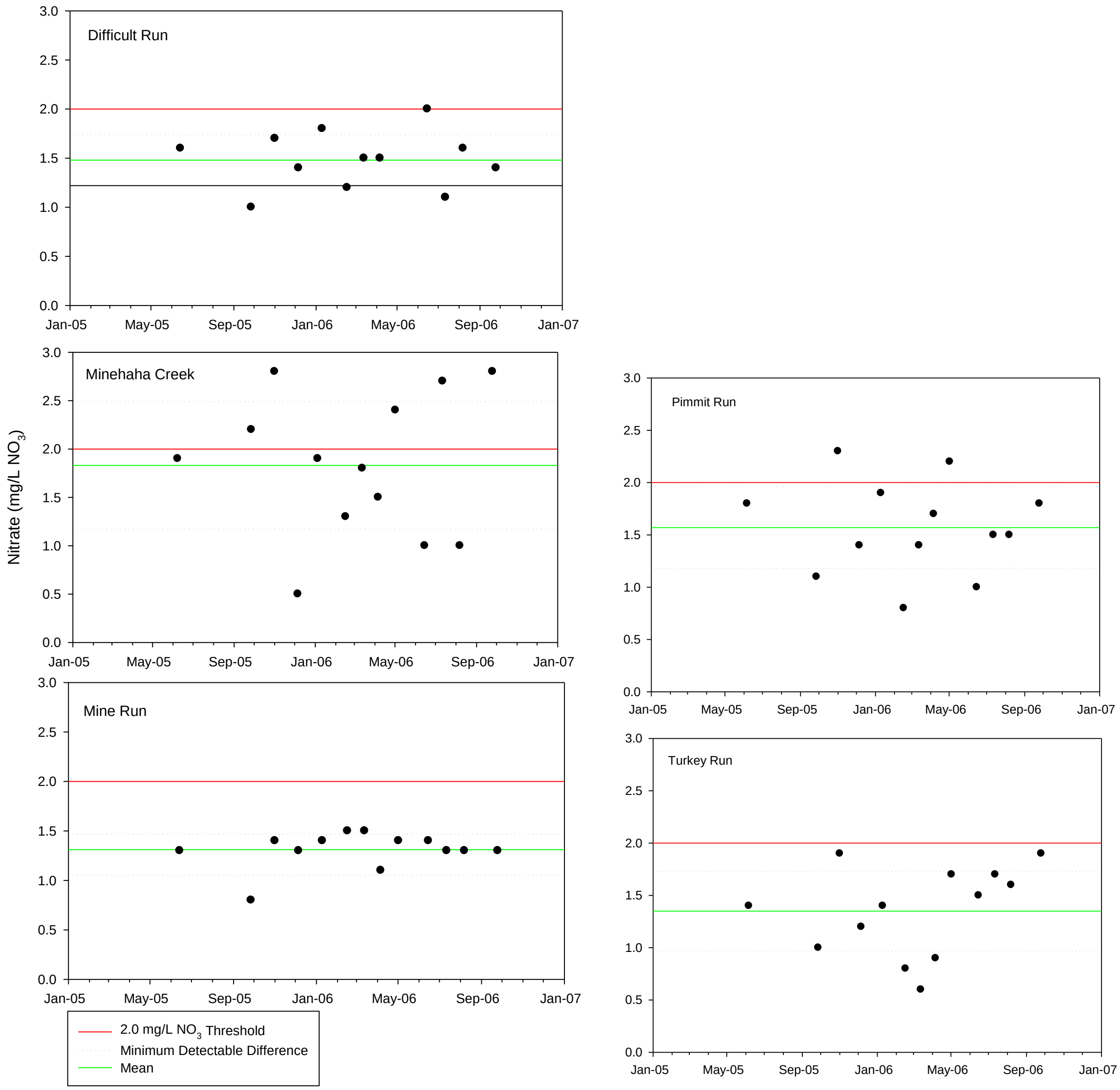

Figure 69: Nitrate in George Washington Memorial Parkway Streams over time.

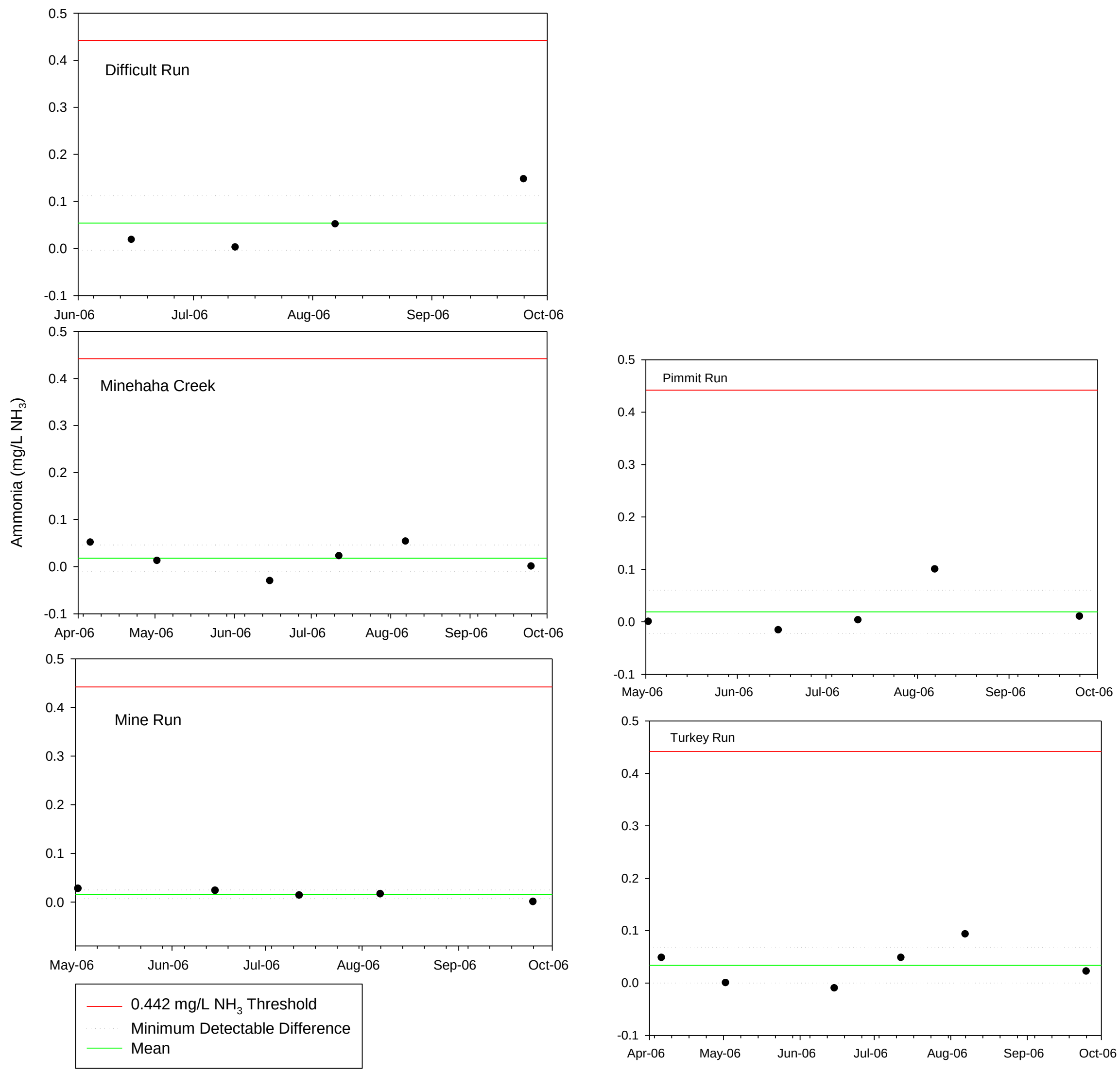

Figure 70: Ammonia in George Washington Memorial Parkway Streams over time.

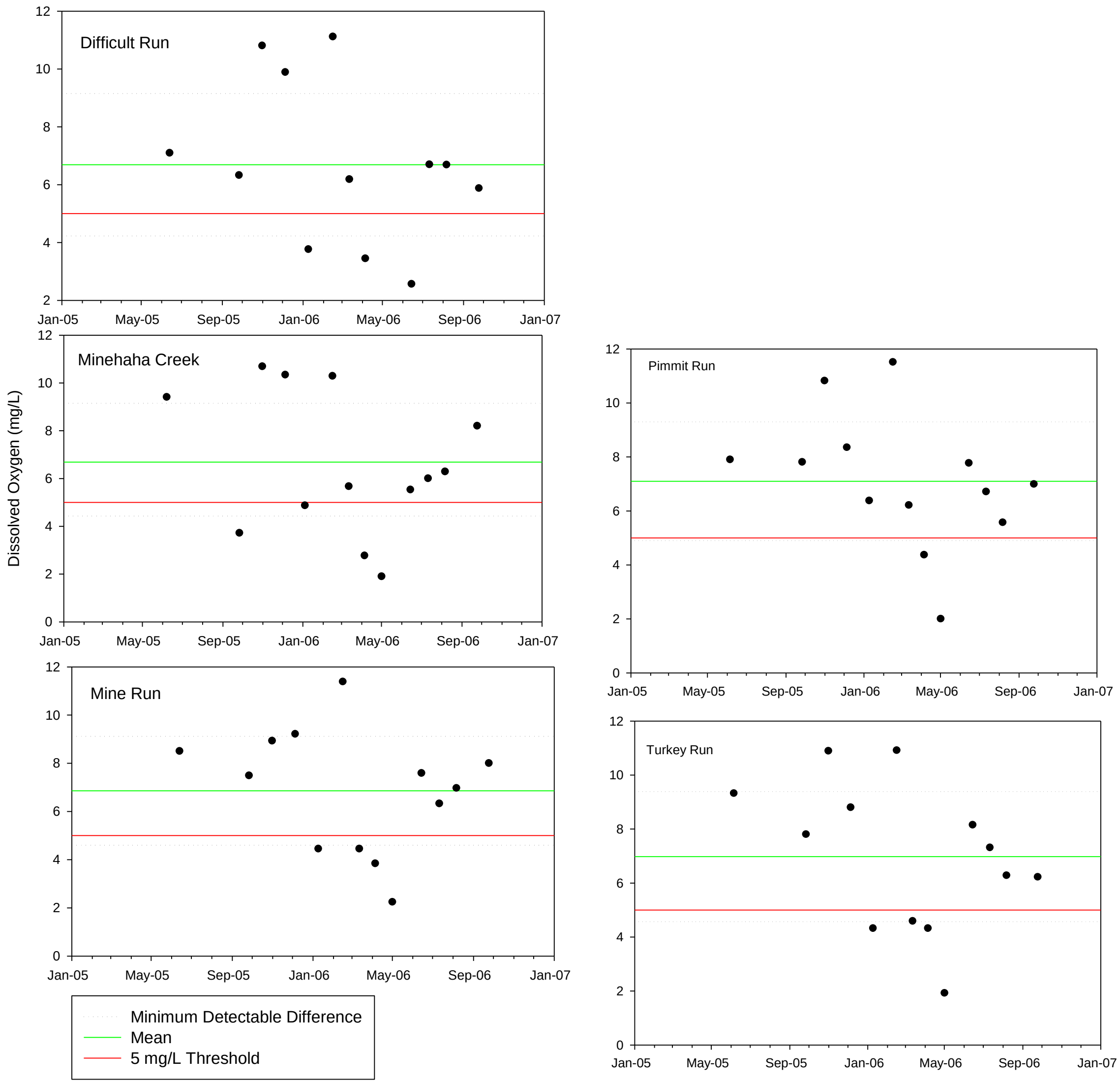

Figure 71: Dissolved Oxygen in George Washington Memorial Parkway Streams over time.

Literature Cited

Allan, J. D. 1995. Stream Ecology: Structure and Function of Running Waters. Chapman and Hall, New York.

Blomquist, J.D., Fisher, G.T., Denis, J.M., Werkheiser, W.H., and Brakebill, J.W. 1996. Water-quality assessment of the Potomac River Basin: Basin description and analysis of available nutrient data, 1970-90. U.S. Geological Survey.

Burke, T.A., J.S. Litt, and M.A. Fox. 1999. Linking Public Health and the Health of the Chesapeake Bay. John Hopkins School of Hygiene and Public Health, Baltimore, MD. [In} Environmental Research Section A 82:143-149.

Fenneman, N. M. 1938. Physiography of Eastern United States, 1st ed. McGraw-Hill. New York and London.

Hem, J.D. 1989. Study and interpretation of the chemical characteristics of natural water, 3rd ed. U.S. Geological Survey Water-Supply Paper 2253. Government Printing Office. Available from the Distribution Branch, Text Products Section, USGS, Alexandria, VA, 263 pp.

Hunt, C. 1967. Physiography of the United States. San Francisco, W. H. Freeman.

Laughlin, C.P. and E. G. Otton. 1964. Preliminary Report on Ground-Water Conditions Along the C & O Canal, Maryland. U.S. Geological Survey. Washington, D.C. 16 pp.

Maryland Department of Natural Resources (MD DNR). 1999c. Maryland Stream Waders Volunteer Stream Monitoring Manual. Chesapeake Bay and Watershed Programs, Monitoring and Non-tidal Assessment. Annapolis, MD.

National Park Service, Water Resources Division (NPS-WRD). 2002. Draft Recommendations for Core Water Quality Monitoring Parameters and Other Key Elements of the NPS Vital Signs Program Water Quality Monitoring Component, Freshwater Workgroup Subcommittee, June 14, 2002, Fort Collins, Colorado.

Norris, M. E., A. Cattani, and J. M. Pieper. 2007. National Capital Region Network Inventory And Monitoring Program Water Chemistry Monitoring Protocol. National Park Service, Washington, District of Columbia.

Otten E.G. and J.T. Hilleary. 1985. Maryland springs – Their physical, thermal, and chemical characteristics. Maryland Geological Survey, Report of Investigations 42. 151 pp.

Radtke, D.B., Davis, J.V., and Wilde, F.D., 1998, Specific electrical conductance, *in* Wilde, F.D., and Radtke, D.B., eds., 1998, Field measurements, *in* National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6.3, 22 p.

Stednick, J.D. and Gilbert, D.M. 1998. Water quality inventory protocol: riverineenvironments. Fort Collins, CO: National Park Service, Servicewide Inventory and Monitoring Program. Technical Report NPS/NRWRD/NRTR-98/177. 103 p.

Strahler, A. N. 1952. Dynamic basis of geomorphology. Geological Society of America Bulletin, 63, 923-938

Thornbury, W. D. 1968. Principles of geomorphology. 2d ed. New York, Wiley.

TNC. 1999. National Capital Region Natural Resource Information Status Report. The Nature Conservancy in cooperation with Lands, Resources, and Planning Natural Resources and Science Services and Natural Resources Advisory Team.

U.S. Army Corps of Engineers (USACE). 1972. Antietam Creek Floodplain Information. Washington County, Maryland. Baltimore District.

U.S. Geological Survey, 1980, National handbook of recommended methods for water-data acquisition—Surfacewater, chap. 1: U.S. Geological Survey, 130 p.

U.S. Geological Survey, 1995. Selected herbicides in major streams in the Potomac River basin upstream from Washington, D.C. NAWQA Fact Sheet 107-95. Townson, MD. 4 pp.

White, William B. 1998. Geomorphology and Hydrology of KArst Terrains. New York; Oxford University Press.

Wilde, F.D., and Radtke, D.B., eds., 1998, National field manual for the collection of water-quality data—Field measurements: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6 [various

William & Mary. 2000. The Geology of Virginia. The College of William and Mary, Williamsburg, Virginia. <URL:http//www.wm.edu/cas/geology/ virginia/coastal_plain.html, piedmont.html, blue_ridge.html, valley_ridge.html, coastal_plain.html>

The U.S. Department of the Interior (DOI) is the nation's principal conservation agency, charged with the mission "*to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities."* More specifically, Interior protects America's treasures for future generations, provides access to our nation's natural and cultural heritage, offers recreation opportunities, honors its trust responsibilities to American Indians and Alaska Natives and its responsibilities to island communities, conducts scientific research, provides wise stewardship of energy and mineral resources, fosters sound use of land and water resources, and conserves and protects fish and wildlife. The work that we do affects the lives of millions of people; from the family taking a vacation in one of our national parks to the children studying in one of our Indian schools.

NPS D-77, December 2007

National Park Service
U.S. Department of the Interior

Natural Resource Program Center
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA [T]